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Experiments with Micro-Elements for the Growth of Crops in Western Australia.

V. EXPERIMENTS AT KULIN (JILAKIN) AND BULLARING IN THE SOUTHERN WHEAT BELT, 1941.

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SUMMARY AND CONCLUSIONS.

1. Experiments with copper-containing fertilisers have given good results on certain types of soil on properties at East Kulin (Jilakin) and Bullaring.

2. Oxidised copper ore, ground and mixed with the superphosphate and supplying similar amounts of copper, gave responses similar to the most favourable bluestone treatments.

3. On very sandy and gravelly soils, bluestone applied at the rate of 10 lbs. per acre proved very harmful and the plots receiving only 2½ lbs. per acre gave the best results.

4. In general practice, for cereal crops on copper deficient land, it is recommended that bluestone, or some suitable substitute containing at least an equivalent amount of available copper, be applied at the rate of 5 lbs. per acre in the first year. For subsequent crops even smaller amounts may be adequate.

5. Manganese sulphate did not prove beneficial when added to the bluestone mixture.

6. On the Kulin property, muriate of potash used in addition to a basal dressing of superphosphate gave only slight increase in yield.

7. The best yield was obtained from the combination of nitrate of soda, superphosphate, muriate of potash and bluestone, but the amount of the increase did not cover the extra cost of the nitrate of soda and muriate of potash.

8. The soils are described and symptoms of copper deficiency in wheat under varying degrees of severity are discussed.

INTRODUCTION.

An exploratory experiment carried out by the authors in 1940 on the property of Messrs. A. P. Carmody and Sons, Jilakin, East Kulin, indicated that the application of bluestone with the usual superphosphate dressing greatly improved

the growth and grain production of wheat on a poor class of wodjil country on Melbourne location 18483. Available details have been published in this Journal (Vol. 18 (2), 95-96, June, 1941). In view of this, in 1941 a more comprehensive experiment was laid down on an adjoining site to determine the effect on the growth of wheat of (a) varying rates of bluestone; (b) substitution of oxidised copper ore for the bluestone and (c) application of both bluestone and manganese sulphate in addition to a standard dressing of superphosphate. A similar experiment was also carried out on Messrs. Bebbington Bros'. property (Avon location 9768), Bullaring, where symptoms, observed in 1940, suggested copper deficiency. In addition, on Messrs. Carmody & Sons property, a small factorial experiment was planted to determine the effect of various combinations of muriate of potash, nitrate of soda and bluestone, on the growth of wheat.

The growing season did not open well and the rainfall was below normal until June, the month of May being exceptionally dry. However, the rainfall was adequate for crop growth in subsequent months and the returns are regarded as satisfactory in view of the soil and climatic conditions. Rainfall data representing the districts in which the experiments were located are given in Table 1.

THE EXPERIMENTS.

Details regarding the nature of the soils will be given after the experimental results have been discussed. At this stage attention will be confined to the preparation of the land, cultural details and observations made during growth.

The land on Messrs. Carmody & Sons' property was not fallowed, but, in view of the virtual absence of grass and herbage, was cultivated in the autumn. Subsequently, the treatments were sown on one-fifth acre plots, using a combined cultivator-drill, on 24th April, 1941.

On Messrs. Bebbington Bros.' farm, the land had been fallowed to a depth of three inches with a disc implement in July, 1940, and springtyned in late September, and again just prior to planting. The treatments were applied with a combined cultivator-drill on one-fifth acre plots on 22nd May, 1941.

In the middle of July, when the crops were at a suitable stage for examination for early vegetative characteristics, little treatment effect could be observed at either site except that the plots receiving 10 lbs. of bluestone per acre were severely retarded in growth at Carmody's and slightly retarded at Bebbington's. Also, at Carmody's the super-only plots were slightly less green in colour but no characteristic lesions associated with copper deficiency showed on either property. Apparently associated with general soil poverty at Carmody's, the older leaves over the whole experiment had yellowed at the tips. Where nitrate of soda had been applied this condition was somewhat reduced and a greener colour generally was induced in the foliage. There was also some evidence of increased growth. The potash increased growth somewhat, but the colour of the plots was very poor.

At the time of this inspection samples of upper leaves were taken for chemical analysis.

When inspected toward the end of September, the Kulin experiment revealed pronounced signs of copper deficiency on the super-only plots: purplish-grey discoloration of leaf sheaths around the stems, dying back and twisting of the ends of the leaves, dummy heads or failure to produce heads at all were the characteristic features of plants on these plots. Plots receiving bluestone at the rate of 10 lbs. per acre carried a very thin crop and some damage was observed on the plots to which bluestone at the rate of 5 lbs., per acre had been applied. Elsewhere, the crop was normal but light. These differences persisted to harvest time.

TABLE 1.

OFFICIAL RAINFALL RECORDS FOR KULIN AND CORRIGIN AND PRIVATE RECORDS FROM FARMS ON WHICH EXPERIMENTS WERE CONDUCTED (IN POINTS).

(Information supplied by the Divisional Meteorologist, Perth, except where noted otherwise.)

(100 points = 1 inch).

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Growing Period May-Oct.	Nov.	Dec.	Total.
KULIN.														
Average 1920–40 inclusive	59	65	109	87	240	227	241	172	121	110	1,111	64	67	1,562
1941	15	12	33	65	90	232	155	210	130	140	957	22	96	1,200
MITCHELLDALE. (9 miles east of Kulin and 6 miles west of Carmody's plots, Jilakin.)														
1941	89	nil	16	63	56	210	251	195	134	92	938	nil	*	...
A. P. Carmody & Sons private Gauge, Jilakin.														
1941	...	...	23	30	92	124	61	175	77	111	640	16	23	732
BULLARING.† (Bebbington Bros.' private records.)														
1941	10	nil	16	83	63	232	110	182	126	112	825	22	45	1,001
CORRIGIN.														
1910–40 inclusive ...	48	55	98	84	206	244	265	212	127	107	1,161	65	67	1,578

* Not available. † Bullaring is 15 miles south-west of Corrigin.

No differences were observed on the Bullaring plots at this date.

However, at Bullaring, differences became obvious in early November. On the super-only plots the leaf sheaths developed the characteristic purplish-grey discoloration, giving the stems a dark colour, and a large proportion of the heads were dummy (contained no grain or very shrivelled grain) and stood erect. The wheat on the plots receiving only 2½ lbs. of bluestone per acre showed these symptoms to a slight degree, and on the plots receiving bluestone at the rate of 5 lbs. per acre occasional patches were similarly affected to a minor degree. By contrast, on the plots receiving adequate copper the plants were typical golden-yellow in colour, the heads were well filled and hanging over with a characteristic curvature of the upper part of the stem.

THE RESULTS.

The treament effects were determined in the latter part of November. Yield estimates were made from cuts taken over the length of the plots on Carmody's property. In order to get an accurate estimate of yield, approximately equal lengths were cut from each drill row except the outside drills. The grain yields were determined by thrashing and winnowing the samples by hand. On Bebbington's property a harvester was used and the total produce from each plot obtained.

The yields from the different treatments are given in Table 2.

TABLE 2.

YIELDS OF GRAIN, TOTAL PRODUCE AND GRAIN : STRAW RATIOS OF WHEAT ON COPPER DEFICIENT LAND AT MESSRS. A. P. CARMODY & SONS' PROPERTY, KULIN, AND MESSRS. BEBBINGTON BROS.' PROPERTY, BULLARING.

Treatment.		A. P. Carmody & Sons.			Bebbington Bros.		
Variety		Bencubbin			Bencubbin.		
Rate of Seeding		50 lbs. per acre			45 lbs. per acre.		
Date Sown		24th April, 1941			22nd May, 1941.		
Date Harvested		25th and 26th November, 1941			27th November, 1941, *et seq.*		
	Rate.	Grain.	Total Produce.	Grain : Straw Ratio.†	Grain.	Total Produce.	Grain : Straw Ratio.†
	lbs. per acre.	bush. per acre.	tons per acre.	%	bush. per acre.	tons per acre.	%
A. Superphosphate	112	0·5	0·29	6	6·2	1·22	16
B. Superphosphate	112	8·2	0·62	54	13·8	1·16	47
Bluestone	2½						
C. Superphosphate	112	6·9	0·54	53	14·3	1·12	52
Bluestone	5						
D. Superphosphate	112	4·1	0·33	48	15·5	1·09	62
Bluestone	10						
E. Superphosphate	112	7·7	....	....	14·6	....	....
Copper Ore	7*						
F. Superphosphate	112	7·6	....	....	16·2	....	....
Copper Ore	14†						
G. Superphosphate	112	6·3	....	....	13·2	....	....
Bluestone	5						
Manganese Sulphate	15						
Difference for significance P = ·05		1·4	·088	6·4	2·4	....	11·4

† Equivalent in copper content to 10 lbs. of bluestone. * Equivalent in copper content to 5 lbs. of bluestone.

The effects of the various combinations of nitrogen, as nitrate of soda, phosphate as superphosphate, potash as muriate of potash, and copper as bluestone, are given in Table 3.

TABLE 3.

RESPONSE OF WHEAT TO VARIOUS COMBINATIONS OF FERTILISERS.

Rates of Application were :

P = Superphosphate—112 lbs. per acre.
N = Nitrate of Soda—*Nil* and 112 lbs. per acre.
K = Muriate of Potash—*Nil* and 56 lbs. per acre.
Cu = Bluestone—*Nil* and 5 lbs. per acre.

Variety—Bencubbin, 50 lbs. per acre. Planted 24th April, 1941.

Fertiliser Mixtures.	Yield.		Grain : Straw Ratio.
	Grain.	Total Produce.	
	bush. per acre.	tons per acre.	%
P + N + K + Cu	8·4	·55	72
P + K + Cu	6·0	·40	57
P + N + Cu	5·7	·36	61
P + Cu	5·1	·38	48
P + N + K	2·6	·36	10
P + K	3·1	·34	15
P + N	1·6	·36	4
P	·4	·15	4
Difference for significance P = ·05 ...	1·9	Not Determined	Not Determined

THE SOILS AND VEGETATION ASSOCIATIONS.

The soils under investigation on Carmody's property, Kulin, have been described in our earlier paper in the Journal (Vol. 18, pp. 95-6). Briefly, they belong to the notorious wodjil group which have generally proved unsatisfactory for wheat growing in W.A. The chief features observed were (a) the gravelly* sandy nature of the surface soils; (b) further concentration of gravel on the subsurface layers; (c) the occurrence of a hard pan at depths of one foot or more; (d) a certain looseness in the sand and gravelly layers.

On Bebbington's property, Bullaring, the experiments were located on country which had carried a vegetation association of stunted wandoo (*Eucalyptus redunca*) and a sprinkling of york gum mallee (*E. foecunda*) with an undergrowth principally of tamma (*Casuarina campestris*) and nigger tea (probably *Baeckea crassifolia*). The site selected was on the lower part of a gentle slope running from a granite outcrop on the east to a small creek on the west. The first plot would be about 4 chains from this creek and near the boundary between the wandoo scrub association and a salmon gum and morrel association along the creek.

The soil was fairly uniform over the experimental area. Profile characteristics included (a) a surface layer of 4 inches of brown loamy sand which gave the soil a favourable appearance; (b) a subsurface layer of yellow more or less gravelly sand somewhat softish in feel; (c) a layer of yellow very gravelly sand to a depth of about one foot; (d) a subsoil of red and yellow gravelly or very gravelly sand which may be more or less cemented.

*The gravel was of a ferruginous type in all soils described in this paper.

On one corner of the experimental area a hard pan or cemented layer was encountered within a few inches of the surface.

Other areas on this farm where copper deficiency of wheat was more or less evident showed similar soil characteristics but concentration of ferruginous gravel was not consistent. It seems most likely that there exists a correlation between the mineral assemblage of the parent rock, and, incidentally of the soil, and copper deficiency. Many soil characters such as accumulation of ferruginous gravel may be of minor importance.

It is of considerable interest that wodjil is not a plant association on copper deficient country at Bebbington's. Tamma and nigger tea appear to occur most generally on these soils on this farm. In many other parts of the State tamma country is regarded as a satisfactory type of light land with no evidence of acute copper deficiency for cereals.

DISCUSSION.

These experiments give further evidence of soil types deficient in copper for the growth of cereal crops and show that the deficiency may be corrected by including a small amount of an available copper compound in the fertiliser mixture.

The amount to be used depends on the soil type involved. Very light sandy and gravelly types, as at Carmody's, require very small dressings of the order of magnitude of 2½ lbs. of bluestone per acre. Even 5 lbs. of bluestone per acre reduced the yield and 10 lbs. per acre had a very harmful effect. On the other hand, on the more loamy and generally superior soil type at Bebbington's, the best returns were obtained from bluestone at the rate of 10 lbs. per acre. Much evidence of copper deficiency was observable where only 2½ lbs. of bluestone per acre were applied and even where 5 lbs. were used copper deficiency symptoms could be identified in patches.

Finely ground, oxidised copper ore, mixed with the superphosphate, may be used on these soil types as an effective substitute for the bluestone and there is little or no danger of a harmful effect if large dressings are applied. As a general dressing it may be recommended that the copper ore be applied to supply copper in amounts equivalent to 5 or 10 lbs. of bluestone per acre. It is not known whether the copper ore will be as effective when not mixed with superphosphate the acidity of which would promote the solution of the copper ore. In all experiments so far carried out, the copper ore has been mixed with the superphosphate.

In most cases of copper deficient land in the wheat belt, it is recommended that bluestone, or some suitable substitute such as copper ore supplying at least an equivalent amount of available copper, be applied to cereal crops at the rate of 5 lbs. per acre. Slightly less may be better on very light soil types and a little more may be more effective on the better types of soil. As dressings as low as 5 lbs. of bluestone per acre have a marked residual value, even smaller applications may be adequate for subsequent crops.

In these experiments manganese deficiency does not appear to be a factor; in fact, manganese sulphate at the rate of 15 lbs. per acre, applied with the bluestone, has slightly reduced yields.

It is recognised that the degree of copper deficiency in soils will vary from slight to very severe. Where the degree of deficiency is more or less slight, the growing crop, or pasture, may not show obvious deficiency symptoms, and the yield may not be materially affected, but some species of plants may be difficult to maintain and the feeding value of the plants growing may be inferior.

Severe copper deficiency is indicated by changes in the vegetative characters of certain plants such as wheat, oats, barley, etc., and these may be recognised in the field. On the basis of these symptoms in the wheat plant copper deficiency may be classified into four degrees of severity.

(a) Very acute—the seedlings show characteristic symptoms in from four to six weeks after germination. Subsequently, the plants die out or continue to produce new leaves as the older ones die off without forming heads.

(b) Acute—vegetative growth is little affected until spring (September). Thereafter leaf tipping occurs, stem elongation is retarded and loose heads with pale, sterile florets are formed. Purplish-grey discoloration of the leaf sheaths give the stems a dark coloration. These conditions were observed at Carmody's.

(c) Severe.—Normal vegetative growth is made until early November when the plants are well headed out and grain formation is expected. Subsequently, the grain does not mature and dummy heads, characteristically standing erect on the stalks, are general. Discoloration of the leaf sheaths is also general. The site of Bebbington's plots would fall in this class.

(d) Moderate.—No differences are observed until maturation. Where the copper deficiency is classified as moderate the heads contain grain but are less well filled. They bend over on the stalk immediately below the head to a very much greater degree than normal. Some discoloration of the leaf sheaths may be observed. This condition has been observed on Bebbington's and other farms in the wheat belt.

It may be asked why the heads are characteristically erect when copper deficiency is severe, and excessively bent over when moderate. From many observations, it is concluded that copper deficiency leads to a weakening of the stems of plants. When there is little or no grain in the heads as in the severe cases, no strain is exerted on the stalk, but when the heads are partially filled, as when the deficiency is moderate, the stalk, weakened by an inadequate supply of copper, bends over excessively.

The grain : straw ratio is greatly affected by copper deficiency. Normally it is expected that the weight of grain will be from 40 to 70 per cent. of the nett weight of straw. Data from the experiments described in this series of papers indicate that, where copper deficiency is moderately acute, the ratio may be less than 30 per cent. and where acute, less than 20 per cent. Grain actually formed where copper deficiency occurs is generally somewhat shrivelled and paler in colour than normal for the variety.

It has been hoped that chemical analysis of the leaves at an early growth stage would be a reliable index of the copper status of the soil. While these hopes have not been fully realised, there is evidence that certain plants may be used as indicators for this purpose. Subterranean clover and lucerne appear to be quite valuable. Oats and wheat, while apparently less reliable, are of some value. Analyses of upper leaves of wheat plants taken in July from super-only and copper treated plots on Carmody's and Bebbington's properties are given in Table 4.

TABLE 4.

ANALYSES OF LEAVES OF WHEAT FROM PLOTS ON CARMODY'S AND BEBBINGTON'S PROPERTIES, 1941.

Analyses as p.p.m. dry matter. Duplicate Samples.

	Carmody.		Bebbington.	
Date Planted	24th April		22nd May.	
Date Sampled	15th July.		15th July.	
——	Super. only.	Super. + Bluestone (10 lbs. per acre).	Super. only.	Super. + Bluestone (10 lbs. per acre).
Copper, Cu, ppm.	3·4	7·7	6·0	8·6
Manganese, Mn, ppm. ...	235	Not Determined	97	Not Determined
Zinc, Zn, ppm.	18	Not Determined	53	Not Determined

Analyses in Government Chemical Laboratory.

Although Bebbington's plots were sown four weeks later than Carmody's, the plants appeared to differ little in stage of growth at sampling and the figures may be regarded as comparative. In both cases the treatment with bluestone has increased the copper content of the leaves but only in the case of the material from Carmody's would the analyses suggest more or less acute copper deficiency where bluestone has not been used as a fertiliser.

The importance of season must not be overlooked. Relative differences in the response to fertilisers may be reduced when conditions are favourable and accentuated when the plants are under stress during growth. Seasonal conditions in 1941 were favourable and would reduce rather than magnify responses to the copper-containing fertilisers.

The use of nitrate of soda and muriate of potash at Carmody's proved disappointing. When used together in combination with superphosphate and bluestone, the best yields were obtained, but the extra yield would not cover the additional expense of the treatment. Muriate of potash, used in addition to superphosphate, slightly improved the yield but, under similar circumstances, nitrate of soda was ineffective.

ACKNOWLEDGMENTS.

The authors wish to express their thanks and gratitude to Messrs. A. P. Carmody & Sons, and to Messrs. Bebbington Brothers, who rendered every assistance possible and went to considerable trouble to ensure that the experiments could be carried out properly, and accurate results obtained.

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Arthritis in Lambs.

C. R. TOOP, B.V.Sc., Senior Veterinary Surgeon.

A disease characterised by severe lameness and stiffness of gait frequently makes its appearance amongst lambs soon after marking. These symptoms result from an inflammatory condition of the joints known as arthritis. The limb joints particularly, become affected. The disease results from the infection of the marking wounds by micro-organisms which are commonly present in the soil. Upon gaining entry to the body the infection is carried by the blood stream to the joints for which the organisms have a special affinity. Here they continue to grow and multiply setting up inflammatory changes accompanied by symptoms of acute lameness.

Despite the severity of the symptoms the majority of affected lambs make a complete recovery after an illness of comparatively short duration. The temporary loss of condition and the check which occurs in the growth of affected lambs constitutes the principal source of loss. For the prevention of the disease, precautions must be taken which have for their object the exclusion of the infection from docking and castration wounds.

CAUSE.

The type of arthritis which commonly affects lambs in Western Australia and indeed the only form of the disease which is of economic importance in this State is caused by the bacillus of Swine erysipelas (*Erysipelothrix rhusiopathial*), a slender rod-shaped organism which is apparently quite common in the soils of sheep yards, camps and paddocks. The organism is obviously very widely distributed and in view of this it is rather surprising to find that no outbreaks of Swine erysipelas have so far been encountered amongst pigs in this State.

In the sheep, this organism has a selective affinity for joints. The great majority of outbreaks of arthritis which occur are a sequel to lamb marking. The organisms gain entry to the body through castration, docking and ear-marking wounds, and upon reaching the blood stream they are carried to the joints where they lodge. Within the joints the organisms continue to multiply setting up the inflammatory condition known as arthritis.

Outbreaks of arthritis, however, are not necessarily associated with lamb marking. Any wound may provide a portal of entry for the infection. In very young lambs infection may occur through the unhealed navel cord while in older sheep cases of arthritis associated with the penetration of grass seeds and with shear cut wounds have been recorded. In addition some severe outbreaks have occurred following the Mules operation for the prevention of blowfly strike and in these cases bush flies which were observed to be present in large numbers have been held responsible for the spread of infection to the operation wounds.

SYMPTOMS.

In many of the outbreaks of arthritis lambs become affected within three or four days of the time of marking. The development of the symptoms may, however, be delayed for as long as fourteen days after the completion of the operation.

The incidence of the disease varies considerably. Quite often only an occasional lamb in the flock may show evidence of the disease. In other cases the majority of the lambs which have been marked may become affected. Both ewe and wether lambs appear to become affected with equal frequency.

Affected lambs appear generally sick. They cease to feed, are dull and tucked-up in appearance and lie down a good deal. Severe lameness affecting one or more of the limbs is the outstanding feature of the disease. When a single limb is affected the animal walks with a very decided limp and may "carry" the affected member. When the lameness affects more than one of the limbs, which is very frequently the case, the gait becomes extremely stiff and cramped. These symptoms are especially marked in the early morning, when the weather is cold. The soreness "wears off" to some extent with exercise and as the day grows warmer.

Any of the limb joints may become affected—the hock, knee and stifle joints, however, are most frequently attacked. When handled, affected joints show no evidence of swelling, heat, or pain. This apparently normal appearance of the joints is rather remarkable in view of the severity of the symptoms.

The great majority of affected lambs make a complete recovery from a few days to two or three weeks from the onset of the symptoms. During this period a good deal of condition is lost and the growth of the animal is checked. This is a matter of considerable importance when lambs are being prepared for the export market and especially so in districts where the season when succulent feed is available is of limited duration.

In a small percentage of cases affected lambs become chronically lame and thereafter do not thrive well. In these chronic cases the joint usually becomes enlarged and the ends of the bones may become fused together, in which case the joint remains permanently stiff or ankylosed. Sometimes the bones become fused together with the joint in the flexed or bent position. This quite frequently occurs in the case of the knee joints in consequence of which the knees may remain permanently bent.

The mortality rate is generally extremely low. An occasional lamb may be lost in the early acute stages of the disease.

POST MORTEM APPEARANCE.

In the acute stages of the disease little or no change will be apparent in affected joints at post mortem. Apart from slight cloudiness of the synovial fluid no departure from the normal appearance will be observed. In the more chronic cases the tissues surrounding the joint are considerably thickened and fibrous, the synovial fluid is scanty in amount, the joint cartilages are somewhat roughened and uneven and adhesions may be present between their surfaces. If the cartilages are removed by boiling, the ends of the bones will be noticed to be quite deeply pitted. When ankylosis has occurred the bones will be observed to have become fused together.

In the case of lambs intended for export, rejections are quite frequently made when there is evidence of arthritis in the dressed carcase. Such carcases are considered to be unsuitable for export purposes and pass on to the local market, usually at a considerably reduced price.

OTHER FORMS OF ARTHRITIS.

In addition to the type of arthritis described above, other forms of the disease are occasionally encountered, these being caused by other micro-organisms principally staphylococci. In such cases there is severe lameness and much enlargement of the joint which sometimes breaks and discharges pus freely. Large quantities of pus are found in affected joints at post mortem. This type of arthritis rarely affects large numbers of animals. It is usually confined to a few sheep only in the flock.

PREVENTION.

In order to prevent the disease, measures should be adopted, the object of which is to exclude the infection from the marking wounds. Old sheep yards should be avoided when marking operations are being carried out. In their stead well grassed temporary yards erected with hurdles, wire netting or other suitable material should be used and a fresh site should be chosen each season. Marking instruments should be allowed to stand in a disinfectant solution when not in use. A 2 per cent. lysol solution, that is, in the strength of 2 oz. of lysol to 5 pints of water, will be found satisfactory. Two sets of marking instruments should be provided in order that they may be interchanged, should the instrument in use become soiled. The hands of the operator should be kept clean by rinsing from time to time in an antiseptic solution. Instruments should be maintained in sharp condition, enabling the operation to be performed rapidly and skilfully, which will reduce the risk of infection and promote rapid healing. After marking, lambs should be set down carefully on their feet, which will prevent tail stumps and castration wounds from coming into contact with the ground. Freshly marked lambs should be released into clean, well grassed paddocks. If measures of this kind are adopted this will reduce the risk of infection to a minimum, which will in turn reduce the number of outbreaks of arthritis which are likely to occur.

Despite all precautions, however, some outbreaks of the disease will still occur, the infection probably being contracted from the dust of paddocks or sheep camps or transmitted by the agency of flies. These are circumstances over which no control can be exercised.

Farm Manure.

M. Cullity, Superintendent of Dairying.

The value of animal excreta as manure has been recognised far longer than can be recorded. It is possible that its use follows closely on the development of cropping.

One passage in a treatise on Husbandry, dating about 50 A.D., by L. Junius Moderatus Columella, states "Yea ashes also and soot have been of great benefit to things that have been either planted or sown; and the stalks of lupins cut down, strengthen as much as the best of dung." This indicates that much practical knowledge about manuring was then known. The value of soot and ashes is recorded, while the soil improving qualities of lupins are compared to dung. This latter fact may be accepted as showing that the application of dung was the standard to which other practices were compared.

The development of Agricultural Chemistry brought forward many theories to explain plant growth. Two of these, Staer's "humus theory" and Liebig's "mineral theory" are of interest; the former because the propounder apparently concluded from the response of plants to applications of organic manures and in the absence of his day of any conclusive evidence that other constituents of the soil and air played any part, that all plant food was derived from the organic matter in the soil. The mineral theory is of interest because of the complete breach with the humus theory. Liebig demonstrated that the very small quantities

of mineral matter which plants contain are important. He pointed out that phosphates and potash were the most important elements in manures, while sufficient nitrogen was washed into the soil from the air by rain.

To-day this view is not completely tenable. While successful growth may be stimulated in water culture without the use of organic matter, there are still many crops which appear to demand the additon of something which is not given in the ordinary mineral mixtures.

However, this article is not intended as an academic discussion regarding the possibility of growing plants with or without organic manure, but to give some information regarding the character of farm manure, how it may be utilised to improve soils and increase returns, and save expense to the farmer.

There can be no disputing the statement that, in farming in Western Australia, there is no real attempt to replace the elements that are removed in cropping.

Superphosphate is applied not by way of maintaining fertility, but as a bribe for a good crop. In order to at least maintain fertility, it is necessary to return to the soil in some form or other those elements removed from it either as a crop or as the product of live-stock farming.

In order to view this proposition correctly, let us look at what is removed in a few crops.

——	N.	Total Ash.	K_2O.	Na_2O.	CaO.	MgO.	P_2O_5.	Cl.	SiO_2.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
30 bushels wheat; 1½ tons straw	50	172	28·8	2·6	9·2	7·1	21·1	2·5	96·9
40 bushels barley; 1 ton straw	49	157	35·7	5·0	9·2	6·9	20·7	4·1	68·6
45 bushels oats; 1¼ tons straw	52	191	46·1	5·4	11·4	8·7	19·4	6·6	88·3
1½ tons meadow hay ...	49	208	50·9	9·2	32·1	14·4	12·3	14·6	56·9
30 bushels field beans; 1 ton haulms	107	157	67·1	2·3	29·2	9·9	29·1	5·4	7·3

This table includes only the more commonly known elements required for plant growth. Modern knowledge takes cognisance of a variety of other substances which play a part in plant growth, but which normally are present in sufficiently large quantities to supply all that are necessary. Occasionally we find, however, that failures occur after a period of satisfactory crops, even though the usual method of manuring may have been followed. As examples of this we can refer to the responses which have followed the application of copper, manganese, and zinc in certain areas of this State. This confirms the belief that continued cropping on a system of replacement of only one element results in depletion of the soil of other elements.

In the clover belt the action of the clover and its symbiotic bacteria results in a building up of nitrogen in the soil, so that this element is safeguarded. Superphosphate is applied as a regular dressing, but apart from stock droppings which usually are allowed to remain where they fall until the action of the weather or trampling of stock break them up and scatter them, nothing else is done to build up the supplies of those other elements which are being taken away in the crops.

It is contended that a systematised use of farm manure will tend to take care of this position and also directly return profit to the farmer by putting his soil in a condition in which it is more capable of producing payable crops.

The good effects which result from the use of farm manure may be attributed to one or more of the following reasons :—

A.—Large quantities of readily available plant food are supplied.

It has been shown by Van Slyke that a cow voids approximately 12 lbs. of solid material in the dung and urine daily. Van Slyke calculated that 156 lbs. of nitrogen, 38 lbs. of phosphoric acid, and 127 lbs. of potash are voided annually. At present values this is worth approximately £9.

In one year a herd of 30 cows would produce almost 60 tons of dry manure containing 4,680 lbs. of nitrogen, 1,140 lbs. of phosphoric acid, and 3,810 lbs. of potash, which is equivalent to the nitrogen in 10 tons of sulphate of ammonina. to the phosphoric acid in two to three tons of superphosphate, and to the potash in nearly four tons of muriate of potash.

It is frequently stated that the fertility of the soil is maintained to a greater extent in dairy farming than under any other system, as the products sold are only a small proportion of the actual yield of the land.

Of the actual food consumed by a cow, approximately 50 per cent. of the nitrogen, 85 per cent. of the potash, and practically all of the phosphoric acid is excreted, and so can be returned to the soil.

Farm manure is therefore a general manure, although probably containing some deficiency in phosphates. However, as superphosphate is the normal and universal fertiliser, the utilisation of the animal excreta in conjunction with it, provides an excellent balance.

From the foregoing some idea may be gained of the quantities of valuable fertilising matter which are neglected on every farm in the State where live stock are kept.

B.—Farm manure exerts a beneficial influence on most soils by improving their physical condition. It assists in rendering stiff clay soils more friable. This is probably brought about by its mechanical effect as well as by some floculating action on the part of the organic acids. Well-rotted manure helps to bind sandy soils, probably by the production of calcium humate, which is a stronger cementing material than clay. It is, of course, obvious that fresh manure containing straw and other fibrous matter would not prove of advantage in porous soils, but would be of real benefit in stiff soils if adequately turned in.

The humus formed from the decaying manure helps the retention of moisture and renders the soil more resistant to wind and rain erosion.

C.—*Bacteria* are introduced into the soil, and these work in a large variety of ways. Farm manures teem with these tiny organisms, which cause chemical changes not only in the manure but in the soil itself, and make available for plant food substances which were previously inaccessible. Probably the most important of these, particularly when manure is used on new poor soils, are the ammonia-producing types which continue their action in the soil producing valuable plant food.

D.—*Chemical action* is promoted in the soil, largely between the acid products of the decaying organic matter and the insoluble minerals of the soil.

That these and similar actions occur is shown readily by the results which follow the use of manure, and which are quite extra to any yield which may be expected by using equivalent amounts of the common fertilisers.

In Western Australia there are approximately 130,000 cows which, on the basis of the voiding per cow of £9 worth of nitrogen, phosphorus, and potash, should provide £1,170,000 worth of these elements annually. There are large numbers of horses, pigs, and sheep which also add to this amount.

However, it must not be assumed that because no attempt is made to utilise the manure that is dropped about yards and bails that there is a complete loss of these fertilising principles. Stock are not housed, and it has been estimated that 75 per cent. of the droppings fall in the open and on pasture.

Inattention to the proper utilisation of this proportion, such as could be obtained by a good system of subdivision and controlled grazing which would allow regular harrowing of the surface, undoubtedly leads to a greater loss than need be. The fact remains that a considerable proportion of the excreta does actually reach the paddocks, where some, at least. is returned to the soil by the soaking of urine and the eventual breaking and scattering of the solid dung.

A greater appreciation by the farmer of the fertilising power which is available in this manure, and his action in devising means of returning systematically to the land that accumulation of manure near homesteads, would lead to greatly increased returns by the building up of the fertility of the soil so that the stock-carrying capacity would be improved.

In the present period of war, actual shortages of certain fertilisers, possible shortages of others, should lead to a greater appreciation of this natural manure which is available on each property.

Difficulties due to shortage of labour will undoubtedly make the utilisation of this manure more difficult than before, but the urgency is greater now.

It is proposed in a further article to discuss methods of conserving and utilising farm manure.

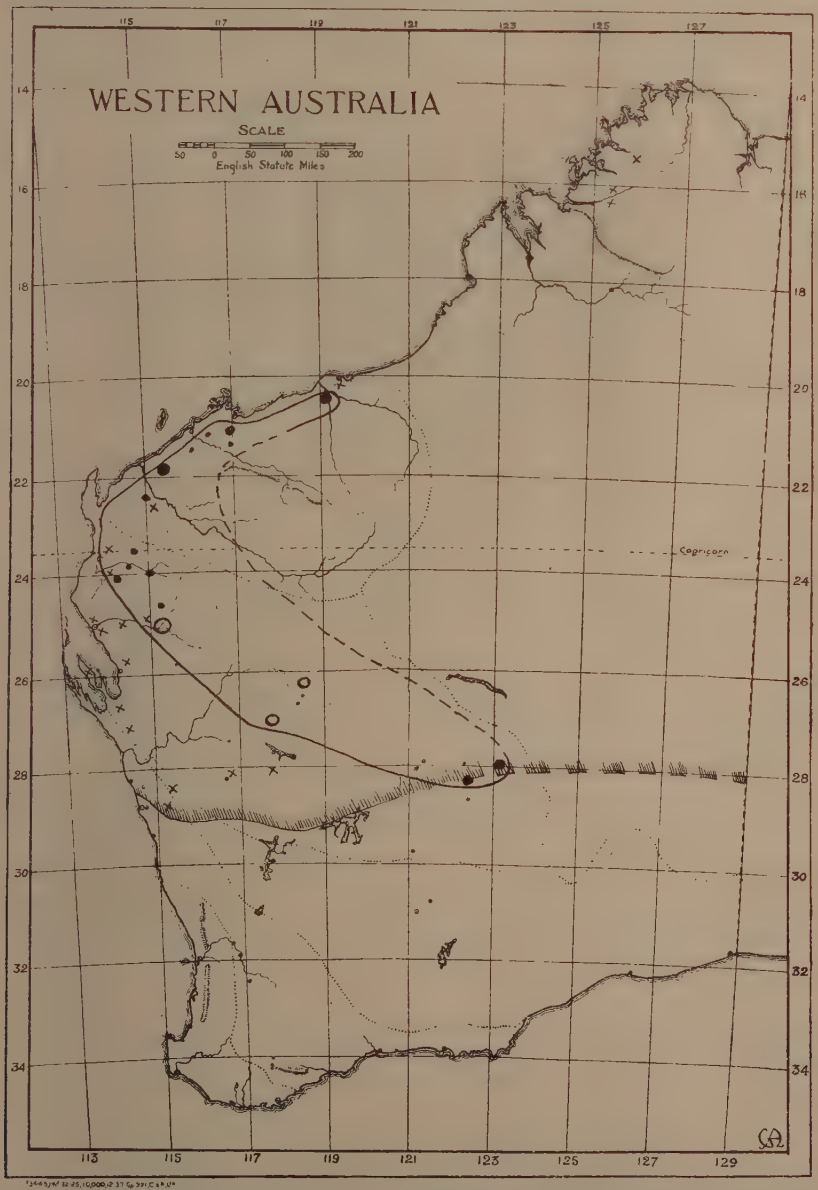
Gascoyne Stock Route Poison Plants.

C. A. GARDNER, Government Botanist.

INTRODUCTION.

Stock mortalities, frequently of a heavy nature, have occurred from time to time on the stock routes of the North-West. These losses have occurred in several districts between the De Grey and Murchison Rivers, and a number of toxic plants have been responsible. At the commencement of the present century, the discovery of *Indigofera boviperda* by Dr. A. Morrison, accounted for the cause of heavy losses on the Ashburton River between Minderoo and Nanutarra. This species had previously been collected on the Gascoyne River by John Forrest in 1882, and determined by Mueller as *Indigofera australis*—an obvious error. A form of the same plant, known as *Indigofera Georgei* occurs freely in the East Murchison, between Lake Darlot and Lawlers, and for a considerable distance to the east of Wiluna. It is very seldom eaten, except by hungry stock. The so-called Flinders River poison (*Tephrosia rosea* F. Muell.) is another species fairly common in watercourses. It has been responsible for heavy losses in Queensland, but its distribution in Western Australia lies mainly to the north of the Fortescue River, few plants being found as far south as the Gascoyne River. The native Lotus (*Lotus australis* Andr.) species of *Isotropis*, of which *I. atropurpurea* is the most dangerous in the

De Grey district, and the Wallflower poison (*Gastrolobium grandiflorum*) found in the same district, but more prevalent in Kimberley, almost completes the list of leguminous plants which at times take such a heavy toll of life.



Map of Western Australia showing the range of *Euphorbia boöphthona*—indicated by black line, and localities where the plant is known to be present—indicated by dots and circles. The range of *Euphorbia clutioides* is that portion of the State to the north of the hatched line, and localities from which the plant is recorded are indicated by crosses.

PLATE I.

Mat balsam (*Euphorbia Drummondii*, Boiss).

A, plant (reduced in size). B, leaf (about six times natural size). C, portion of branch showing leaves and flowers (six times enlarged). D, two views of cyathium ("flower"). E, stamen. F, fruit. (All details enlarged.)

Of plants containing known alkaloids, there are the various species of Nicotiana, the native tobacco plants, and the indigenous thorn apple (*Datura Leichhardtii*) most frequently met with along watercourses, but these plants are not readily eaten by stock on account of their unpleasant odour, and poisoning is usually rare.

There is another class of toxic plants which are for the most part harmless, but which, under certain conditions may contain prussic acid in such quantities that they become dangerous to stock. These cyanogenetic plants include a number which may be useful at times, and are even considered to be valuable feed. They include a number of grasses and wattles, and the best known example is probably Johnson grass (*Sorghum halepense*). During recent years a number have come into prominence in this connection because of the heavy toll of life for which they are responsible. Notable amongst them is the native fuchsia (*Eremophila maculata*), Drummond's balsam, or mat balsam (*Euphorbia Drummondii*), and several species of goosefoot (*Chenopodium*). Other plants cause photosensitisation, such as species of *Tribulus*, of which there are a number in the North-West. In some cases the nature of the toxic substance is not known, and a slender blue-flowered plant known as *Morgania floribunda*, for many years suspected in the North-West, and as far south as Geraldton, has recently been found by Dr. Seddon to be toxic to stock.

Toxic plants when eaten by stock cause symptoms by which they may sometimes be recognised, and cyanogenetic plants as far as they are known, cause much the same symptoms —a form of bloating in which foam is exuded from the mouth, a dark blue colour of the mucous membranes, staggering and collapse, the head being usually thrown back. Amongst the post-mortem appearances in animals skinned shortly after death, is a flow of dark blood from both the skin and the subcutaneous tissues, the lungs and liver contain much blood, and there is usually foam in the windpipe.

HISTORY.

From time to time during the last 30 or 40 years, losses in cattle and sheep have occurred on the Gascoyne River, near its confluence with the Lyons River, near Jimba Jimba homestead, and on Bidgemia station. Many thousands of animals have been lost in this district, and stockmen and drovers defined the area as that portion of the De Grey River—Mingenew Stock Route between the Binthabooka Creek, which flows into the Lyons River, and the Gascoyne River crossing, and along the Gascoyne River from Bidgemia to Winnemia wool shed on Jimba Jimba station. The losses experienced were so heavy, that during recent years drovers have been seeking for an alternative stock route in order to avoid this area. In September, 1941, the Hon. Minister for Lands and Agriculture (Mr. F. J. S. Wise) issued instructions for a survey of the affected area to be made, with a view to discovering the poison plant responsible, and the possibility of finding an alternative route free of this poisonous plant, if it existed. I accompanied the survey party led by District Surveyor Stokes which made this survey, spending three weeks in the district, during which time a careful examination was made of the vegetation.

The result of the survey was a collection of some four hundred species of plants, all of which have been determined, and of this number the following are known to be toxic to stock:—

Nicotiana ingulba J. M. Black.
Datura Leichhardtii F. Muell.
Lotus australis Andr.
Tephrosia rosea F. Muell.
Tribulus spp.
Morgania floribunda Benth.
Euphorbia Drummondii Boiss.
Euphorbia boöphthona C. A. Gardn.

PLATE II.

Gascoyne Poison (*Euphorbia boöphthona*, C. A. Gardn.).

A, plant (slightly reduced form of small plant). B, leaf. C, small portion of branch showing leaves and "flowers." D, a cyathium or "flower," slightly enlarged. E, gland of "flower." F, seed, many times enlarged, and showing wart-like excrescences. G, base of seed, showing the hat-shaped caruncle. H, Persistent peduncle and axis of fruit. (All details enlarged.)

The symptoms described by pastoralists indicated to us that the trouble was due to some cyanogenetic plant, and the affected area was exactly that of the local range of *Euphorbia boöphthona*. This plant was first collected by me at Junga Creek, where in 1935, fifty-seven bullocks, and more than a thousand sheep had died in one week on the stock route about 35 miles north-west of Cue. The trouble occurred during a very dry season when feed was scarce; the bullocks were found dead in the morning after watering and camping for the night. In making an examination of the stock route in the vicinity I noticed that they had eaten freely of a patch of a *Euphorbia*, which at the time was determined as *Euphorbia eremophila* A. Cunn. Seddon and Hindmarsh had experimented with *Euphorbia eremophila* in New South Wales in 1929, but secured no positive results. They found, however, that *Euphorbia Drummondii* was, under certain conditions, toxic to stock, and this latter species has been responsible for heavy losses in New South Wales and Western Australia. *Euphorbia Drummondii*, however, was only seen very infrequently at Junga Creek, and certainly not in sufficient quantities to cause the losses which were sustained. In investigating another case of poisoning from the stock route near Meekatharra, I again discovered this so-called *Euphorbia eremophila*. Here 150 cattle and 300 sheep had died. An aqueous extract of the plant, representing about 2 lb. of the fresh plant, but in a wilted condition (the season again being very dry), was taken to Perth, where a test for toxicity made by the Veterinary Pathologist (Dr. H. W. Bennetts) resulted in the death of a sheep. The symptoms were strongly suggestive of cyanogenesis. It was in August, 1932, that I first saw this *Euphorbia* at Jimba Jimba where a number of sheep had died some time before my visit.

Although the specimens agreed very well with the description of *Euphorbia eremophila*, it was noticed that there were two distinct forms of this species, and that the form present at Junga Creek, near Meekatharra and at Jimba Jimba, was different to that which is common in sandy soils in the north-western littoral from Kimberley to Geraldton.

In 1938 I examined the type specimen of *Euphorbia eremophila* in the Kew Herbarium. This specimen was collected by Cunningham at Shark Bay in 1822, and described in 1844. It was found to be the same as the common littoral species referred to above, and to be identical with a specimen from the Pacific island of Tanna determined in 1786 as *Croton clutioides* Forst. fil. (*Euphorbia tannensis* Speng.) (*E. vieillardi Baill.*) I have therefore separated the two plants previously described as *E. eremophila*, and renamed them *Euphorbia clutioides* (Forst. f.) C. A. Gardn., and *Euphorbia boöphthona* C. A. Gardn. The former is the species which was tested by Seddon without positive results, while the latter is the species found to be toxic. *E. clutioides* has an extensive range embracing New Zealand, Melanesia, Queensland, New South Wales, South Australia, the Northern Territory, and Western Australia from Kimberley as far south as Geraldton and Mullewa. *E. boöphthona* on the other hand is restricted to the Eremaean Province of Western Australia, and extends from the De Grey River in the north to the lower Murchison River, Laverton, Wiluna, and as far east as Lake Carnegie.

The original description of *Euphorbia boöphthona*, and the new combination *E. clutioides* are described in the Proceedings of the Royal Society of Western Australia, vol. xxviii, at present in the press.

The two species can usually be separated by the leaf, which, in *E. boöphthona* is acute and of a bright green colour, and the plants widely branched; in *E. clutioides* the leaf is usually longer, and is blunt at the apex, and has a blue-green colour. Any doubt can at once be removed by an examination of the seeds; those

of *E. boöphthona* are large and conspicuously warted or papillose, and the aril separated from the seed by a narrow constriction, while the fruits are pendulous and speckled with white; *E. clutioides* on the other hand has small seeds which are smooth or only slightly roughened, and the aril is contiguous with the seed; the fruits are small, green throughout, and more erect.

THE RANGE AND DISTRIBUTION OF EUPHORBIA BOOPHTHONA.

The plant is found occurring sporadically over a wide area extending from the De Grey River to Cue, Meekatharra, Laverton, and eastwards from Laverton. There are no records from north of the De Grey River, nor is it recorded from other States.

The centre of its distribution is the Gascoyne watershed. Here its eastern limits are not known, but it is prevalent along the Arthur and Wyndham Rivers which flow into the Gascoyne River near Bidgemia; that portion of the Lyons River to the south of Davis Creek; the Gascoyne River from above Bidgemia as far west as Scorpion Well; and along the lower reaches of Daurie Creek. It is found in clay or silty soils along these watercourses, and diffused over the stony clay flood plain to the south of Jimba Jimba, between the homestead and Jacob's Gully, near Winnemia. The limits of this southern extension are not known, but the species extends at least forty miles south of the Gascoyne River. Where the soil is sandy the plant is entirely absent, or an occasional depauperate specimen is seen in sandy soil amongst sandstone rocks. It is entirely absent from the "Wannu" and "Junga" country. It is in fact a plant restricted to watercourses and clay stony plains south of the Gascoyne River. Its range in this district coincides with the area where poisoning has been experienced on the stock routes traversing it. It is most gregarious in the clay and silt of the banks of streams.

In the Murchison district it has been found at Junga Creek near Cue, westwards to Meekatharra, and at Laverton, in all cases occupying watercourses or depressions in clay or stony clay soil.

Passing northwards from Davis Creek on the Lyons River, the plant is no longer in evidence, but it reappears sporadically distributed on watercourses running into the Minilya River. On the Minilya itself, the plants are very scarce, very few being found in sandy spots near creeks, and none along the river. At Wandagee it occurs in sandy stony places, especially where sand has accumulated around rocks, and it is rare in the loamy soil. To the north of the Minilya River it is still more scarce, and the communities found were invariably in red sand, often associated with Triodia ("Spinifex"). The areas seen were small, and very infrequent. Mixed with Triodia it occurs northwards to Peedamullah and Roebourne, and southwards to near Mount Herbert on the Hamersley escarpment, but was not seen on the sandy country of the Hamersley Range itself.

It is doubtful if it occurs in sufficient quantity north of the Minilya River to be the cause of any serious losses in stock except in places where large patches occur, as is the case near the woolshed at Peedamullah. A point of interest is that, in passing out of the Eremaean Province into the North-West Province it ceases to be a species of alluvial soils, and becomes a psammophyte.

EUPHORBIA BOOPHTHONA RESPONSIBLE FOR GASCOYNE STOCK ROUTE POISONING.

As stated earlier, there was strong evidence to suppose that *Euphorbia boöphthona* was toxic to stock. There was the field evidence, the presence of the plant in localities where large numbers of stock had died from poisoning strongly

PLATE III.

Euphorbia clutioides (Florst. fil.), C. A. Gardn.

A, portion of plant, showing habit of growth. B, leaves (+ natural size). C, "flower," or cyathium (enlarged). D, seed showing small asperities and caruncle at summit.

suggestive of cyanogenesis at Junga Creek and Meckatharra and Jimba Jimba, all on stock routes, and finally the test conducted in Perth with material from Meckatharra, which gave a positive result. A close examination of the affected parts of the De Grey-Mingenew Stock Route between Davis Creek and Bidgemia, as well as the affected portion of the Carnarvon route, showed that the area affected coincided exactly with the distribution of *Euphorbia boöphthona*. The symptoms of poisoning are the same as those described for *Euphorbia Drummondii*, a plant found in several places throughout the State, but certainly not in sufficient quantities on the affected portions of the routes to be accounted responsible for the heavy losses experienced. Portions of the Stock Route regarded as being free from the trouble were also free of *Euphorbia boöphthona*.

It has been objected that if this species were really toxic to stock, losses amongst pasturing station animals should be experienced as well as those suffered amongst travelling stock. This in fact, strengthens the evidence, for in the case of *Euphorbia Drummondii*, losses in pasturing sheep are very infrequent, whereas travelling stock are poisoned. Shortly before our arrival at the Gascoyne River, Mr. E. Bostock of Jimba Jimba Station, lost thirty-eight rams and two wethers in two areas which he told me he could definitely associate with previous losses. A survey of the two revealed the presence of *Euphorbia boöphthona*; in area "a" it was dominant, while in "b" it was very scarce, but I was informed that the sheep lost here had, a few hours before death, travelled over a small area heavily infested with the poison. An interesting feature of the area "b" was that there was a fair quantity of *Morgania floribunda* growing in a clay watercourse.

SYMPTOMS OF POISONING.

I was unable to see animals which had died from poisoning, but stockmen at meetings and in the course of private conversations, agreed that when sheep were poisoned they exhibited the following symptoms:—

> The animals affected are usually hungry travelling stock. The trouble occurs in dry weather, usually in seasons when feed is scarce, and according to some observers, in the morning following one or two fairly heavy precipitations of dew. The losses occur at any time of the year, but mostly between July and the end of October. They were described as being similar to the symptoms observed following the ingestion of native fuchsia (*Eremophila maculata*).

The circumstances under which mortality occurs are frequently as follows:—

> After watering in the evening at the river, the sheep are collected and penned, and the following morning a number are found dead. Other sheep, apparently healthy, develop symptoms when driven. The animals drop, are unable to rise, the head is bent backwards, and a pink foam exudes from the mouth. A drooping of the ears has also been observed. Occasionally an apparently healthy animal will rear and drop dead. There is little or no struggling, and bloat does not occur. If sick sheep are rested they may recover. When opened, the stomach contents are yellow, and the carcase is yellow under the skin.

These symptoms agree substantially with those given for *Euphorbia Drummondii* poisoning in New South Wales. This plant is common in all the States of Australia, and local cases of poisoning are on record. The death of some sheep on Callagiddy Station occurred during 1941 in a sandy area in which this plant was

present in some quantity. It is common on the red sand hills around Carnarvon, and doubtless has been responsible for at least some of the losses which have been sustained there.

PREVENTION.

Poisoning due to prussic acid in plants is common in many countries. Dr. D. G. Steyn, writing in "Farming in South Africa," January, 1940, on the subject states: "As poisoning follows a rapid course, and prussic acid is a deadly poison, much value cannot be attached to remedial measures. Every attention should therefore be given to prevention. Since it has been repeatedly proved by experiment that sulphur is a good preventive for prussic acid poisoning, stock-owners are recommended to take the following measures: The animals should have access to sulphur licks, and, where minerals are deficient—where the animals show a desire to eat bones, rags, etc., to any extent—one part of sulphur to every nineteen parts of lick should be supplied. Animals can be poisoned by an excess of sulphur. Full-grown sheep and goats may with safety be given two level teaspoonsful of sulphur daily over a number of years, and cattle and horses one tablespoonful. When severe cases of poisoning are expected or are occurring, it is advisable to give sheep each a heaped-up teaspoonful, and cattle and horses each a tablespoonful of sulphur every fourth day, while at the same time they should have access to the above-described sulphur licks. As sulphur is sometimes prepared from ores containing arsenic combinations, it is advisable to obtain a certificate from the seller to the effect that the sulphur does not contain dangerous quantities of arsenic.

"Where tanks and watering troughs are available, sodium thiosulphate ('hypo') could be dissolved in the drinking water. In very dry and hot weather, when animals will drink large quantities of water, 'hypo' should be dissolved at the rate of 1 lb. per two hundred gallons of drinking water. When climatic and other conditions are such that stock will consume less water, one lb. of 'hypo' could be dissolved in every one hundred gallons of drinking water. Some types of water (hard and alkaline and acid waters, and water to which superphosphate was added, etc.), will precipitate the sulphur from the 'hypo,' but this will not interfere with the efficacy of 'hypo' as a preventive. Animals consuming 'hypo' water should not have access to licks containing more than one part of sulphur to nineteen parts of lick.

TREATMENT.

"Since prussic acid poisoning runs a very rapid course, treatment is usually of doubtful value unless the animals are treated at an early stage of poisoning. Sodium thiosulphate ('hypo') is the best remedy. For cattle and horses the dose is one-quarter to two teaspoonsful (15-150 grains) according to age and size, dissolved in two teaspoonsful to three tablespoonsful of water, and injected into the jugular vein. The solution should first be boiled for a few minutes and allowed to cool before being injected. Further, cattle and horses may each receive, according to age and size, one teaspoonful to two tablespoonsful of the remedy in a small quantity of water, dosed by the mouth. Sheep and goats should receive one-quarter of the dose recommended for cattle and horses. The above dosing can be repeated after four hours if no improvement occurs."

THE STOCK ROUTE SURVEY.

The survey of the affected part of the stock routes between Lyons River wool shed and Gascoyne Junction, and as far south as the "Boundary Store" on Daurie Creek, as well as the Carnarvon route between Gascoyne Junction and the vicinity

of Scorpion Well to the west of the vermin proof fence, revealed the fact that *Euphorbia boöphthona* extended along the watercourses between Davis Creek and as far westward as two miles to the west of the vermin-proof fence, also along Daurie Creek as far as the boundary store, but that it was scarce on the Lyons above the Binthabooka Creek, and on the Gascoyne River to the west of Winnemia. Between these points, especially between the Gascoyne Junction and Jimba Jimba homestead, it was common. The botanical survey showed that of suspected plants this plant alone was common to the area. Other plants known to be toxic, such as *Lotus australis, Euphorbia Drummondii, Tephrosia,* and *Datura Leichhardtii* were not common throughout the affected area, nor were they in any quantity, although there is the possibility that they are to some extent responsible for some losses. It was noteworthy that at the watering places, such as Mungarra Well, Jimba

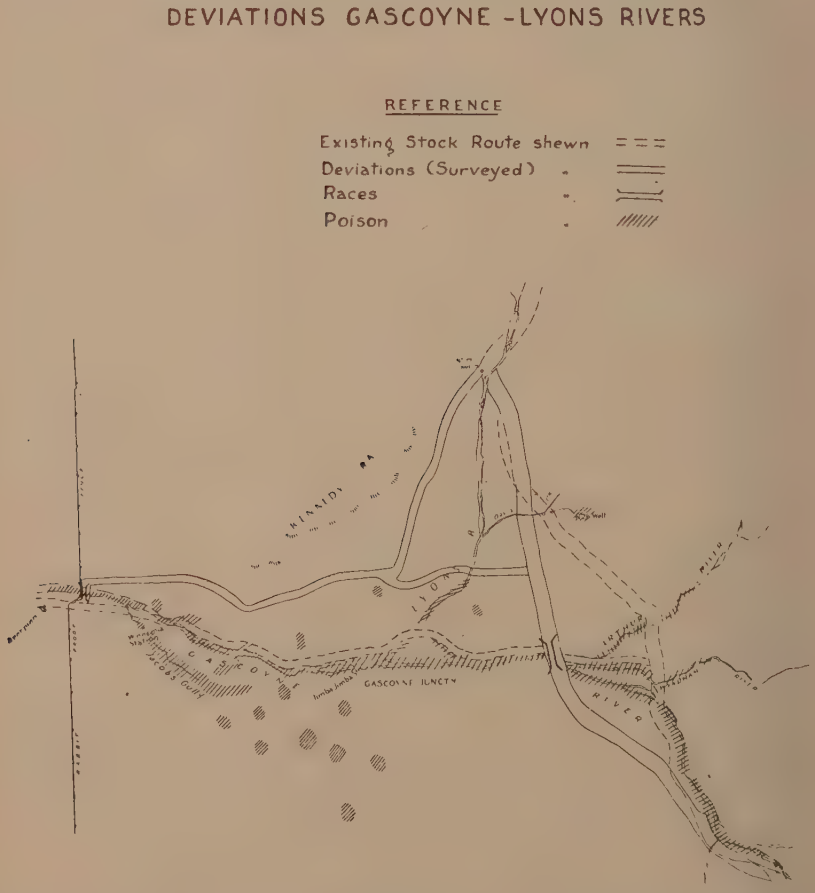


PLATE IV.

Sketch map showing portion of the De Grey-Mingenew stock route in the vicinity of the Gascoyne River, the Carnarvon stock route, and the areas infested with *Euphorbia boöphthona* (indicated by hatching).

Jimba and Winnemia, the plant was present in large quantities. It was not found away from the rivers except in small quantities in the tributary creeks on the south side, and a few depauperate plants on the stony country, but it was present in abundance on the stony clay flats to the south of the Gascoyne River as far west as Jacob's Gully, and as far east as Jimba Jimba homestead, and for some miles southward. As far as examined, the Lyons River to the north of Davis Creek, as well as the Creek itself, except for a small patch near No. 28 Well, were entirely free of the plant. It should be noted that although stock frequently travel down the Lyons River from No. 27 Well, the stock route from this point travels to the south-east past No. 26 Well, and across the Arthur and Wyndham Rivers to No. 24 Well on the Gascoyne River. The crossings of the Arthur and Wyndham rivers are also heavily infested with the plant.

It was noticed that the country to the north of the Gascoyne River between Davis Creek and the vermin-proof fence, was almost entirely free of *Euphorbia boöphthona*, but the Kennedy Range provided a barrier through which no direct practicable route could be discovered. The only possible route across this country was found to be through a narrow pass, locally called "Calvary Gap," near the southern end of the Kennedy Range, and this was found to be free of the toxic plant. From this point, a route was discovered passing westwards, at some distance north of the river, to the vermin-proof fence. Here the route follows the fence across the Gascoyne River, connecting with the existing route into Carnarvon. A sketch map, showing this deviation, surveyed by District Surveyor S. J. Stokes, is appended by kind permission of the Surveyor General. It shows also the surveyed alternative route for the De Grey-Mingenew stock route which provides a poison free detour to avoid crossing the Arthur and Wyndham Rivers. The provision of a "race" or "run-through" on the Gascoyne crossings will facilitate the rapid transit of stock across the infested watercourses.

SUMMARY.

A survey was undertaken last September and October, to discover the cause of stock poisoning in the Gascoyne district along the De Grey-Mingenew and Carnarvon stock routes which have resulted in the loss at various times of several thousand cattle and sheep. Apart from two species of Nicotiana, and the species of Tribulus indigenous to the area, the following toxic species were found: *Datura Leichhardtii F. Muell., Lotus australis Andr., Tephrosia rosea F. Muell., Morgania floribunda Benth., Euphorbia Drummondii, Boiss* and *Euphorbia boöphthona C. A. Gardn.* The symptoms described by local stockmen and drovers suggested a cyanogenetic plant. *Euphorbia boöphthona* was the only species occurring in large quantities, and its distribution in the district coincides with the area affected. *Euphorbia boöphthona* has been separated from *E. clutioides* (*Forst. f.*) *C. A. Gardn.*, and is held responsible for other stock losses in the Cue and Meekatharra districts.

The survey, undertaken by District Surveyor S. J. Stokes, resulted in poison-free alternative routes or deviations being discovered.

Copper Deficiency of Cattle and the Fatal Termination "Falling Disease."

H. W. BENNETTS, Veterinary Pathologist,
R. HARLEY, Government Veterinary Surgeon and S. T. EVANS, Assistant Research Officer, Council for Scientific and Industrial Research.

For some time now officers of the Stock Branch of the Department of Agriculture, assisted by the Council for Scientific and Industrial Research, have been investigating the problem of copper deficiency of cattle in this State. The principal object of this work was to determine to what extent sudden deaths in cattle, known popularly as "falling disease," were due to this deficiency. We have now almost conclusive evidence that these sudden deaths are the direct result of a severe and prolonged deficiency of this element: "falling disease" is not a distinct disease entity, but is the terminal phase of a condition of copper deficiency. It is, therefore, better to describe the condition as "sudden death" or fatal copper deficiency.

Apart, however, from this very striking manifestation the effects of the non-fatal deficiency are very definite and are of considerable economic importance.

The purpose of this article is to give a concise account of the various manifestations of copper deficiency in cattle and how to prevent them.

Details of experimental work and other observations have been given in progress reports, published from time to time, by Bennetts (1941) and Bennetts *et al.* (1939, 1939 a, 1941, 1942.)

OCCURRENCE.

Large tracts of Western Australia are known to be copper deficient. Areas in the South-Western portion of the State where the copper content of pastures has been found to be low and where stock exhibit signs of deficiency have been detailed and mapped by Beck (1941).

Cattle depastured in these areas show signs of illness varying in severity with the degrees of deficiency in pastures. They appear to be most severely affected in that proportion of the jarrah red gum belt extending from just north of Busselton to several miles south of Margaret River and within about 15 miles of the coast line. The Northcliffe district is similarly affected. Throughout these areas the results of analyses of pastures and animal tissues indicate a widespread severe degree of copper deficiency. Sudden deaths ("falling disease") were commonly experienced.

Country in the Walpole, Nornalup and Napier Settlement Areas is also deficient to a varying degree. Other parts of the extreme South-West, e.g., Denmark, as reported by Underwood and Beck (1941), are marginal: the copper content of pastures is somewhat low but cattle and other stock do not show definite signs of deficiency. As elsewhere, affected areas merge into marginal or healthy country.

Further North the Gingin and Dandarragan districts are known to be deficient although not so severely as the Busselton-Margaret River-Northcliffe area. Although sheep show marked signs of deficiency, cattle are affected to a much less degree, definite evidences being confined, practically, to calves. It would appear that sheep are more susceptible than cattle.

Coastal country is also known to be copper deficient but here manifestations in stock are frequently overshadowed by a complicating deficiency in cobalt which gives rise to the progressive wasting characterising "coast disease" (Bennetts, 1940).

Copper deficiency is known in some inland agricultural districts but generally areas affected are patchy and small in extent so that stock have access to adequate "sound country"; moreover few cattle are carried. Other areas, notably semi-coastal country in the region between Perth and Bunbury are suspected but have been investigated incompletely.

There is little doubt, however, that time will reveal the presence of copper deficiency in still other areas. In this connection we have already ample evidence that cultivation and pasture improvement associated with increased rate of stocking tend to develop an incipient deficiency; some country which in its unimproved state carried stock more or less satisfactorily following improvement becomes progressively more unhealthy for animals which, with the progress of years, may show very marked evidence of deficiency.

Seasonal conditions also have a definite effect. Signs of deficiency are more marked in the months of August to October and, in general, are more evident in favourable seasons with abundance of green fed than in dried years when pasture is shorter and less rank.

Unless the deficiency is severe young stock particularly are affected. Calves reared on their mothers show more evidence than those weaned at an early age as is customary in the dairying districts. If the deficiency is of a mild degree the former may be the only members of the herd showing obvious signs of illness.

Of adult animals, cows subjected to the stresses of breeding and milk production appear to be more susceptible than dry cows, bulls or steers. If the deficiency is severe "sudden death" may ensue.

SYMPTOMS.

1. Non-fatal Copper Deficiency.

Calves may show signs of deficiency at an early age. Growth is retarded and there is marked unthriftiness. The limbs show abnormalities—pasterns are straight and calves tend to stand up on the toes. Joints, particularly those of the hind limbs, are "knobby" as a result of bony prominences. These clear up as the animal reaches the age of 1½-2 years. Diarrhoea and signs of anaemia are commonly noted. With increasing age the animals grow very slowly and have a very stunted, undeveloped and unthrifty appearance. On some holdings they cannot be reared into profitable members of the herd and are destroyed. Maximum size is not attained in adults on the worst affected properties and each successive generation tends to be smaller in frame.

Adult cattle show signs attributed to copper deficiency. Manifestations are particularly marked during the period from August to October when, despite abundance of green feed, there is some loss of condition and the coat is very rough and "starey." A grave anaemia, definitely due to copper deficiency, is commonly present during this period; recovery from this is rapid and spontaneous during the early Summer months.

Depraved appetite is common; cattle eat soil around the roots and butts of upturned trees. Scouring is frequently present. Temporary sterility with sup-

pression of oestrus is an associated condition; many cows served during the Autumn and Winter months, although failing to get in calf, do not return to the bull generally until November or December when they are readily stocked.

The signs of ill health detailed above can be controlled by the administration of copper supplements. Extensive observations to this effect confirm experimental findings indicating that they do result from copper deficiency.

It should be remembered however, that temporary sterility, particularly the type in which there is a history of regular heat periods, may be due to a number of causes apart from copper or other mineral deficiency. At the same time there is no doubt that the use of copper supplements has greatly facilitated the stocking of cows in the deficient areas.

2. Fatal Cases of Copper Deficiency—"Sudden Death" ("Falling Disease").

As reported previously "sudden death" ("falling disease") occurs only in areas which are severely deficient in copper. Cattle only are affected. "Sudden death" has not been reported in horses, sheep or pigs.

Cows die, generally, when from 4 to 7 years of age but not uncommonly when older. "Sudden death" is uncommon in younger animals and is not known to affect cattle under 15 months old. Male animals are rarely affected. Reports indicate that death occurs most frequently just before or within a week or two after calving. It is most frequently observed when cows are being brought in to be milked, are standing in the bail, or are being driven out to paddock again. In some cases the cows have actually fallen on the milker. Deaths also occur when cows are at pasture but are not observed very often. A cow, apparently normal in health, suddenly bellows, throws up its head and falls dead. Death frequently appears to be instantaneous. Sometimes the animal falls and struggles feebly on its side on the ground for a period varying from a few seconds to five minutes. In these cases of longer duration intermittent bellowing, running movement of the legs and attempts to regain an erect posture are also noticed. Finally the animal lies stretched out with head back and dies.

The following is a settler's account of a death witnessed by him:—

"When I first started bringing the cows home she was perfectly normal and grazing with the rest. I had got them about halfway home when she stopped and started swaying on her feet, she seemed to be paralysed and could not move, she also seemed to be forcing water from herself. She then started to stagger with her head down, as if she was drunk, after that she fell flat on her side and rolled completely over with her back downhill, her legs and neck stretched out straight and her legs quivering. She gave a few groans, her back legs doubled up and she turned partly over on her back, her legs then went straight again and she was dead. She died within one minute and a half of when she she started to sway."

Rarely an animal may show symptoms for 24 hours or more, intermittently pivoting with the head down, before dying suddenly in the typical manner. Three such cases were observed by H. T. B. Hall.

Recently it has been shown that copper supplements prevent the occurrence of "sudden death" under controlled experimental conditions. This evidence from small groups of cows at Jindong, near Busselton, confirms very extensive observations of the successful prevention of "sudden death" by the use of copper supplements under practical farming conditions.

POST-MORTEM CHANGES.

The carcase of a copper deficient animal, killed for examination, or of a case of "sudden death" shows no characteristic changes to the naked eye. There may be some evidence of anaemia and malnutrition; the heart may be flabby. In fatal cases the carcase is congested; the veins are full of blood because of the failure of the heart which precedes and is, apparently, responsible for "sudden death."

On microscopic examination the changes found in the organs of fatal and non-fatal cases of copper deficiency are very similar. The most constant finding throughout is a more or less marked accumulation of iron in the liver, kidney and spleen (melt). The significance of this has been discussed in publications referred to. In cases of "sudden death" and in some non-fatal cases of copper deficiency there are very definite changes in the heart muscle. It is found, commonly, that quite extensive areas of heart muscle have disappeared and been replaced by scar tissue (atrophy and fibrosis). These serious changes are, at present, attributed to the direct and indirect effects or prolonged severe copper deficiency.

The causes and nature of these heart changes are being studied in more detail.

The microscopic changes found, constantly, in the kidneys in "sudden death" are quite characteristic; similar changes have never been observed in non-fatal cases and have not been described in any other disease. The nature of these changes, described elsewhere, indicates that they occur within a short time of death and result from the factors which are immediately responsible for the sudden death of copper deficient cattle.

THE EVIDENCE THAT "SUDDEN DEATH" ("FALLING DISEASE") IS THE TERMINAL MANIFESTATION OF COPPER DEFICIENCY.

It has been demonstrated, almost conclusively, that the sudden death known as "falling disease" is the final result of severe copper deficiency.

The evidence, discussed fully in publications referred to, may be summarised as follows:—

Extensive investigation failed to incriminate any germ or any plant or chemical poison. The detailed changes occurring in the body of copper-deficient cattle killed for examination, are essentially similar to those which die suddenly. These changes, in both cases, are ascribed to the effects of the deficiency. It has been shown quite definitely that "sudden death" occurs only from pastures which are very deficient in copper and in herds where the copper content of the blood and liver of animals is also very low.

During the past season it was demonstrated in an experimental herd at Jindong, near Busselton, that the regular administration of an adequate copper supplement would prevent the occurrence of "sudden death"; cases occurred in the control group which received no copper whereas cows in the copper-drenched group remained in good health throughout. This evidence from small groups of experimental cows confirms extensive observations from a large number of herds in the Busselton-Margaret River-Northcliffe areas that copper supplementation prevents the occurrence of "sudden death" under practical farming conditions.

Nevertheless a more detailed and progressive study of the nature and development of the disease processes, in cattle maintained under conditions of severe copper deficiency, will be necessary before it can be stated *with complete confidence* that "sudden death" is entirely the result of copper deficiency.

THE CAUSE OF DEATH IN FATAL COPPER DEFICIENCY.

It has been emphasised that "sudden death" is known to occur only in cattle maintained for long periods on pastures severely deficient in copper. Affected pastures contain, generally, only about 1 to 2 parts per million of copper (Cu, dry basis). It does not occur on pastures, *e.g.* those at Gingin, where the copper level is somewhat higher, about 2 to 4 p.p.m. Pastures on which animals show no evidences of deficiency contain over 5 p.p.m. of copper, as stated by Beck (1941).

Cattle kept on deficient pastures are unable to obtain from them a supply of copper adequate for the body's needs. Dairy cows in particular become very anaemic during the spring months.

It is considered that the effect of long continued copper starvation and of the anaemia recurring each season leads to progressive and permanent deterioration of heart muscle which is replaced more and more by scar tissue. As already pointed out these grave changes may be found in cows which still appear to be relatively healthy. Ultimately the disease process becomes so extensive or vital parts of the organ are affected so that the heart is no longer able to continue beating; "sudden death" results from heart failure.

Death occurs almost invariably during the August to October period. It is during this time of the year that various stresses on the animal and consequently the demands on the heart are most severe: a grave anaemia is commonly present and blood copper values are at their lowest level, growth and production are stimulated by the bulk and quality of the spring pastures. "Sudden death" commonly occurs soon before or after calving and it is obvious that breeding would impose a severe strain on a cow in the state of health indicated. Seasonal factors, not fully understood, appear to have a bearing on the manifestations of copper deficiency including the terminal one.

In brief, "sudden death" is a product of the extent and distribution of the diseased condition of the heart and of the effects of various stresses to which the animal is subjected during the spring of the year.

RELATED DISEASES OCCURRING ON "COASTY" COUNTRY WHICH ARE POSSIBLY DUE TO COPPER DEFICIENCY.

Two conditions apparently distinct from "Coast disease" have been reported from the copper and cobalt deficient "coasty" areas of this State. These are, firstly, deaths in undriven good conditioned cattle not seen sick but found dead frequently near their watering place, and secondly, "driving disease."

The evidence that these conditions are due to copper deficiency is entirely circumstantial; no adequate investigation has been practicable. There is reason to believe, however, that the former condition, which generally affects cows heavy in calf, is actually the "sudden death" ("falling disease") which we have described as the terminal manifestation of copper deficiency.

The second condition has been reported also from King Island by Dumaresq (1942) who described it as "driving disease." On description there seems no doubt that this is identical with the disease commonly experienced in herds depastured for some months on coast country to the west of Gingin. Dumaresq describes "driving disease" as follows:—

"This is another rapidly fatal disease of cows on coast country. It has been found that when cows are left on coast country for three months or more sudden death often occurs *when they are driven.* This is especially the case with

pregnant cows. According to descriptions by local stockowners who have had experience of 'driving disease,' affected animals suddenly drop while being driven in the mob though sometimes the beast staggers for a few steps first. The animal is visibly distressed and a little urine dribbles from the vulva without the usual lifting of the tail. *If the cow is allowed to remain quite undisturbed at this stage it usually recovers. Should it be forced to move, however, it immediately drops dead.* Numerous stories are told of cows falling over dead at the crack of a whip. As affected animals are reported to be often in good condition there would not appear to be any evidence of 'coasty disease.' There is also no evidence of overdriving."

Stockmen in this State report also a loud thumping heart beat and pronounced jugular pulse in distressed animals; subjects are commonly cattle which show some evidence of "coast disease" but this is not invariably the case. Recovery is said to be, apparently, complete after a short sojourn on healthy country.

In this State both conditions, described above, occur in cattle changed from copper deficient country inland to the, apparently, more severely copper deficient coast country.

On King Island Dumaresq has definitely confirmed the presence of "falling disease" and of the other signs which we have attributed to copper deficiency. Here also all appear to have responded to copper supplements. He has demonstrated a very low copper content of pastures and a low copper status of animals. On King Island, however, "driving disease" has been noted only when cattle have been for some months on the coast country where, apart from a severe copper deficiency, cobalt is also deficient. He has not been able to investigate the disease.

The evidence available suggests that "driving disease" is probably due to the same cause as "falling disease." It would appear possible that in these cases the heart changes have progressed only to a degree where severe exertion is necessary to produce heart failure. It may be that a complicating deficiency of cobalt is a contributory factor in "driving disease."

On a large coastal property west of Gingin, cases of sudden death and "driving disease" occurred annually over a period of years. Since 1938 copper and cobalt supplements have been administered, in the drinking water, to cattle while on this coast country during the period March to July. These supplements were successfully used to prevent "coast disease." It is rather significant that no cases of sudden death or "driving disease" have occurred in the herd of 300-400 cattle since this treatment was instituted whereas previously these conditions were encountered annually.

THE CONTROL OF COPPER DEFICIENCY DISEASE.

Since 1938 a considerable bulk of experimental and field evidence has accumulated that the various manifestations of ill-health, described in this paper, can be controlled by the administration of adequate copper supplements. The use of these throughout the affected area and in particular in the severely deficient Busselton-Margaret River and Northcliffe districts has resulted in the prevention of the sudden deaths known as "falling disease" and in the maintenance of better health in herds generally; less difficulty has been experienced in getting cows stocked and the growth and development of young cattle has been materially improved.

The use of copper supplements in the affected areas can, therefore, be recommended with a degree of confidence although our knowledge of copper deficiency disease in cattle is still far from complete.

With regard to *sudden* deaths occurring in undriven and driven cattle on "coasty" country, however, it should be remembered that the cause of these conditions is undetermined and the evidence that copper (and cobalt) supplements are preventive is very limited.

Copper supplements may be administered to cattle in the following form:—

1. "Denmark Lick."

The feeding of Denmark Lick has been the method most generally adopted throughout the affected areas in the South-West. This lick, in addition to copper and other ingredients, contains a percentage of phosphorus and cobalt which may also be deficient in the pasture in some affected areas. This lick has proved very effective for the control of copper deficiency disease. It is a valuable one for general use, particularly so where a complicating deficiency of cobalt is suspected.

Dose—

Cattle, 2 years or over	2oz. daily
Yearlings	1oz. daily
Calves	½ to 1 oz.

The doses may be doubled without ill-effects but should not be reduced. Where practicable measured amounts should be given in feed; this ensures that all animals receive an adequate quantity. If they are merely given free access to lick in the paddock some animals may take large amounts whereas others get little if any. If desired the lick may be fed in the milk to hand-fed calves or given as a drench suspended in water to all stock.

2. Bluestone Solution.

Observations and investigation indicate that with the exception of "coasty" country our copper deficient areas are not to any great extent deficient in cobalt or in various other minerals contained in the Denmark Lick; at Jindong, experiments extending over a four-year period have shown that the response to copper alone was as good as that obtained when other minerals in addition to copper were fed.

There is evidence, therefore, that a supplement containing copper alone may be recommended generally. The advantage is that bluestone solution is much cheaper to use than the Denmark Lick.

The Bluestone Solution. First make a strong stock solution by dissolving ¼ lb. bluestone in 1 quart of water. For use take 1 fluid ounce of this and add sufficient water to make up to 1 pint of dilute solution. Glass or non-metal containers should be used for mixing and storing solutions.

Doses of Dilute Solution:—

Cattle 2 years or over	2 fluid ounces daily
Yearlings	1 fluid ounce daily
Calves	½ to 1 fluid ounce daily

The *dilute solution* can be administered mixed with feed given once daily to each animal in the bail. If this is impracticable drenching would be necessary. The

solution should be given at least three times a week, the doses in that event being twice those given above.

Note:—In areas where moist patches of green feed are restricted or absent during the summer months cattle maintained on dry feed may require phosphatic supplement in addition to the bluestone treatment—this can be given in the form of dicalcic lick or bonemeal throughout the dry period.

3. Topdressing Pasture with Copper Compounds.

It has been shown that the copper content of mixed pastures, in the deficient areas, can be raised to normal values following topdressing with copper compounds mixed with superphosphate. Cattle and other stock do particularly well on these pastures from which they all receive amounts of copper quite sufficient for their requirements. This is undoubtedly the best method of supplementation under dairying conditions. Here the expense incurred is more than compensated for by the remarkable improvement in the quality and quantity of pasture which results from the topdressing. This is particularly so in the severely deficient areas where subterranean clover has "stalled" and been replaced by the drooping flowered variety. There is evidence that, in these areas, subterranean clover can be re-established with the aid of copper treatment. It appears, too, that stock carried on the topdressed pastures do even better than on untreated pasture plus copper compounds administered as supplements.

For topdressing, bluestone is applied generally at the rate of 5-10 lb. per acre mixed with superphosphate. Teakle (1942) states "Oxidised copper ore mixed with superphosphate is equally effective and considerably cheaper but is not easy to obtain at the present time. It should be bought strictly on analysis and applied in the first year in amounts to supply 2 to 3 lb. of copper per acre." Copper compounds other than bluestone are also effective. It is known that the beneficial effects of a dressing of copper-containing fertiliser persists for a number of years. The Department of Agriculture has a number of experiments in progress to determine necessary applications in subsequent years but no recommendations can be made until the results have been obtained over a period of years. Until these results are available it may be suggested that small dressings, say equivalent in copper content to 2lb. of bluestone per acre, be applied in succeeding years.

It has been observed that regeneration of sub. clover pasture by copper-containing fertilisers is frequently delayed until the second, or even the third season, but, on copper deficient land, the result is commonly spectacular.

SUMMARY.

In a number of districts in this State, pastures have a low copper content and stock maintained thereon show signs of copper deficiency.

The manifestations in cattle have been discussed. These vary in degree according to the severity of the deficiency. Young stock show evidences of malnutrition and retarded growth and development. In older animals signs of illness are unthrifty appearance, anaemia, depraved appetite, scouring and, commonly, temporary sterility. The last named, however, may be due to causes other than deficiency.

Breeding cows are particularly affected and signs of copper deficiency are most evident during the spring months.

If the deficiency is severe the termination may be sudden death, known as "falling disease." This is ascribed to heart failure resulting from an extensive deterioration of heart muscle, due to the direct or indirect effects of prolonged and severe copper deficiency, and the sum of various stresses operating on the animal during the spring of the year.

Sudden deaths in driven ("driving disease") and undriven cattle on "coasty" country are considered to be related conditions but the actual cause has not been demonstrated.

The various manifestations of copper deficiency which have been described can be controlled by the use of adequate copper supplements; these may be administered in the form of Denmark Lick, bluestone solution or through pastures topdressed with copper compounds incorporated in the usual superphosphate dressing.

ACKNOWLEDGMENT.

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Some Poultry Pests.

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INTRODUCTION.

The poultry industry is an important source of revenue to many people in this State. During the year 1939-40 the net value of recorded production in Western Australia amounted to over £290,000. It is thus evident that any pests which adversely affect the domestic fowl (the principal class of poultry cultivated) are worthy of careful consideration.

Fowl parasites may be divided into two main types—internal parasites and external parasites. It is only the latter which concern the entomologist. There are a large number of insects, ticks and mites which may be associated with birds,

some permanently and others intermittently. Most bird species have their own parasite fauna and many interesting problems of adaptation and relationship have been shown to be associated with this specialisation, but such matters are beyond the scope of the present article.

As is so often the case with pests of domestic animals, fowl parasites are now practically cosmopolitan in distribution. There are two main groups to be considered -the ticks and mites and the true insects including lice, fleas, etc.

Ticks and Mites.

Ticks and mites in their adult condition possess four pairs of legs and so can be distinguished from insects which of course only have six legs, but for practical purposes the former are often grouped with insects under the heading "Insect Pests of Poultry."

The Fowl Tick (*Argas persicus* Oken).

The first record of this pest in Western Australia was made in 1897 at Northam, and since then it has spread throughout the warm and dry parts of the State. The effects of fowl tick on the birds are often severe to the point of death. The ticks cause the birds discomfort at night by loss of sleep, but a more serious result of their activity is the loss of blood by the bird, and the possible introduction of the parasite causing the disease known as "tick fever." Young chickens are usually most seriously affected.

Symptoms of "tick fever."—The bird shows a loss of appetite, a rise in temperature, restlessness, blackness and shrinkage of the comb, and diarrhoea followed by paralysis and often death. Those fowls that recover have a degree of immunity from further attacks of the parasite.

Fig. I.
The Fowl Tick: Adult female, upper and lower sides (enlarged).
[From U.S. Dept. Agr.]

Hosts.—Hosts of fowl tick include the domestic fowl, ducks, geese, turkeys, pigeons, ostriches, canaries, wild birds and sometimes cattle.

Description.—The fowl tick is an oval, rather flattened creature, one-quarter to one-third of an inch long, without eyes, and with colour varying from light reddish brown to dark brown, depending on the amount of blood it has engorged. It has piercing and sucking mouth parts.

Habits and Life History.—In habits it is very similar and in appearance not unlike the common bed bug. It is essentially a night feeder, hiding in cracks and crevices during the daylight hours. Only the small six-legged "seed" ticks are found attached to the birds during the day as well as at night. As this period of their life is of short duration (5-10 days) it shows how easily an infestation can escape notice and puzzle anyone who finds birds unthrifty and yet carrying no parasites on them during the day.

The adult female tick lays eggs in batches of 50-100, and there are usually several layings totalling 500-900 eggs. These are brownish in colour, spherical and about 1/40th inch in diameter. They are usually laid in sheltered positions such as the cracks of perches and between pieces of wood used in the construction of the fowl house. These eggs hatch in from 2-4 weeks into the six-legged "seed" tick which migrate during the night to the bird and attach themselves. The most favoured places of attachment are the breasts, thighs and under the wings. The "seed" ticks remain here for from 3½-10 days and engorge a large quantity of blood which is to last them over the next stage of their life. At the end of the feeding period, they are 1/10th inch long and drop from the birds to the ground. They then crawl into a crack, and after a week moult and emerge as an eight-legged tick in every way resembling the adult except in size. These small ticks only feed at night and return to the cracks in the day time. They moult several times, each time increasing in size until they become adult. The period between the hatching of the egg and attainment of maturity is, under ideal conditions, about five weeks, but it may take considerably longer, as the tick can survive in any stage for long periods without feeding. "Seed" ticks may endure a fast for 5½ months, and adults have been known to survive four years of starvation. This fact is important in controlling this pest, as it is useless to try to starve it out and dangerous to take timber from old long disused fowl houses for the construction of new ones.

The bark of trees also forms a good hiding place for ticks, especially in cases where unbarked bush timber is used for building purposes or where birds roost in trees. Also, ticks will travel considerable distances along fences to other fowl houses. The eggs may be carried on old crates, etc.

CONTROL.

Precautionary measures.—The old proverb "prevention is better than cure" is especially appropriate when dealing with pests. If one erects a building which offers little protection to ticks, an accidental infestation may be easily eradicated. The houses should be built with new timber or with material obtained from clean premises, and if bush timber is used it should be secured from an area to which tick infested birds have not had access. Any cracks should be painted with tar, and suspended perches should be used wherever possible. Sheds constructed of angle iron and galvanised iron offer a minimum of harbourage to the pest but the initial outlay is high.

Finally, quarantine newly bought fowls in coups to make sure that they are tick free, particularly in the case of male birds. Two weeks quarantine is advocated.

Treatment of Premises. The difficulties associated with eradicating ticks from a hen house are so great that in the case of a structure of little value, after the removal of the iron, burning is recommended as saving considerable time and trouble. Rebuild on new ground and treat the old site with creosote. In any case, if a house is infested, burn all litter, nesting straw, boxes, timber, etc., which is lying around. All cracks and crevices should be sprayed under strong pressure with one of the following preparations:—crude oil, creosote or kerosene emulsion* at about 1 in 8. This should be repeated every 2-3 weeks until no more live ticks can be found. Finally paint all wood work and cracks with hot tar, as this will help to seal the cracks.

Birds infested with "seed" ticks should be isolated and treated by rubbing the affected parts, i.e., breast and under wings, with an ointment of lard and kerosene.

The Poultry Mite (*Dermanyssus gallinæ* DeG.).

Commonly called the red mite, this is a cosmopolitan pest of poultry and thrives under a wider range of conditions than the fowl tick, which has a distinct preference for warm surroundings. The mite attacks adult poultry as severely as young chickens. As with the tick, it normally feeds on the birds at night, leaving them during the day to return to the cracks and crevices of the perches, walls and surrounding woodwork of the pens or nest boxes. They have a habit of congregating in groups and it is not uncommon to find swarms of them under the roosts

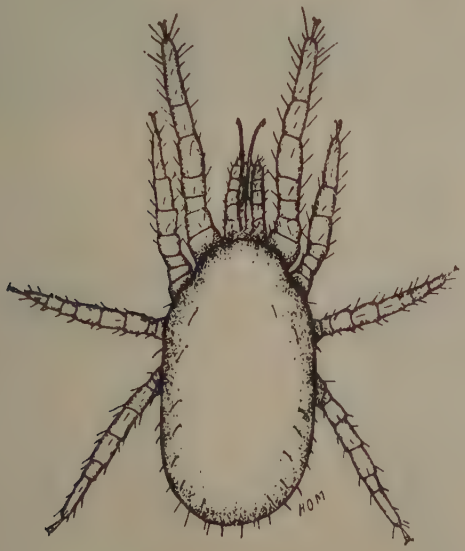

Fig. II.
Poultry Mite (enlarged).
[After Mönnig.]

*For preparation of kerosene emulsion, see appendix at end of article.

or to find them attacking a sitting hen in the daylight, but generally they leave the bird when they have engorged enough blood. The results of their attack may be fourfold:—

1. They may cause great reduction in egg production.
2. By constant feeding and irritation of the skin of the birds they may cause sitting hens to leave their nests, and even die.
3. In severe cases they may cause great loss of flesh, unthriftiness, and reduction of vitality.
4. They may transmit poultry diseases from infected birds to healthy ones.

Fig. III.
Old roost showing excreta following mite infestation.
[From U.S. Dept. Agr.]

Hosts.—The hosts of the poultry mite include pigeons, fowls, turkeys, pheasants, and occasionally domesticated animals, and man himself.

Description.—The mite is a small pear-shaped, grey to red creature measuring 1/30th to 1/40th of an inch in length with eight legs and piercing-sucking mouth parts. They are not easily seen individually, but their habit of congregating together makes them noticeable.

Life History.—The adult female lays her tiny white, shiny, oval eggs in her daylight haunts, i.e., the cracks and crevices of perches, nest boxes, etc. The eggs hatch in from 2-6 days, depending on the temperature, and a small six-legged mite emerges. The latter begins to feed, and after several engorgements, sheds its skin and becomes an eight-legged mite resembling an adult except for size. After several more engorgements of blood and subsequent moults, it becomes mature. This development takes from 1-2 weeks, but depends largely on the temperature, the parasites being relatively inactive in cold weather.

In the absence of a host the adult mites can remain alive in infested houses for 4 or 5 months.

CONTROL.

The control measures for this pest are directed chiefly at the hiding places, and the same control measures as for the fowl tick may be adopted. One should be wary of old timber, etc., when constructing fowl houses, and also isolate any introduced bird for some days.

When an infestation has been noticed all litter, spare boxes, etc., should be removed and burnt. Roosts and nest boxes should be removed to facilitate spraying, and replaced by something more suitable to future clean ups if necessary. When the house has been swept out it should be sprayed thoroughly under good pressure with one of the following:—

Kerosene emulsion 1 part to 8 or 10 parts of water;

or

Lime sulphur 1 part to 8 or 10 parts of water.

Repeat in a week's time. A third application may be necessary.

Also run undiluted black leaf 40 at the rate of $\frac{1}{2}$ ounce per 100 feet along perches half an hour before the fowls go to roost.

Scaly Leg Mite (*Cnemidocoptes mutans* Robin & Lanq.).

This is another mite which is not an uncommon pest of poultry. The general symptoms are a thickening of the legs on the scaly portions due to the burrowing of the mites into the skin. This causes the scales to protrude and exudation to take place, which cakes on the outside. The infection generally starts on the toes and spreads upwards. Scaly-leg is very readily transmitted from bird to bird.

Fig. IV.
Healthy shank and foot of fowl.
[From Jour. Agr. Vict.]

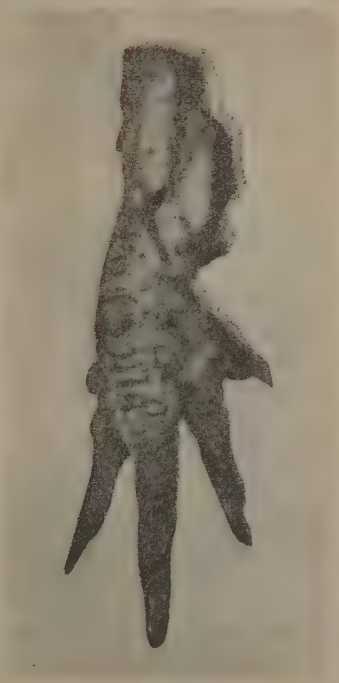

Fig. V.
Shank and foot of fowl affected with scaly-leg mite.
[From Jour. Agr. Vict.]

Fig. VI.
Scaly-leg mite.
[After Mönnig.]

Hosts.—Common hosts of the scaly-leg mite are domestic fowls, turkeys, pheasants, pigeons, and cage birds.

Description.—The adult mite which measures about 1/80th of an inch in length, burrows into and lives in the skin. The female deposits her eggs in this position and on hatching, the young mites migrate to set up fresh colonies of infestation on the same bird, or on other birds which may be reached per medium of the perches.

CONTROL.

Soak the legs in warm soapy water and scrub with a hard brush. After this apply an ointment of lard to which has been added some sulphur and kerosene (7 parts lard to 3 parts sulphur 1 part kerosene). Dipping the feet in kerosene will give good results, but getting any on the feathered portions of the leg may result in some burning. Repeated treatments may be necessary.

Treatment of the perches must also be carried out by painting them with old sump oil or kerosene.

The Depluming Mite (*Cnemidocoptes laevis* var. *gallinae* Railliet).

The depluming mite is closely allied to but slightly smaller than the scaly-leg mite. It has a comparable life history but attacks the fowl near the base of the feathers instead of on the legs and toes. Its attacks start on the body and may progress to the neck, head and thighs. The mites themselves do not cause the bird to lose its plumage but the intense itching they produce impels the bird to pluck its feathers in an attempt to reduce the irritation and a bald patch soon results. The affected quills will be found surrounded by scales and crusts and this condition frequently spreads rapidly.

Hosts.—The common host is the domestic fowl, but it also attacks other birds such as pigeons, pheasants, etc.

CONTROL.

The control of this mite is effected by the use of an ointment of lard, kerosene and sulphur applied to the affected parts, also by dipping the birds in solutions containing either 2 ounces of flowers of sulphur and ½ ounce of soap to each gallon of water, or ¾ ounce of sodium flouride per gallon.

Lice and Fleas.

Lice.—There are about 40 species of lice which are known to occur on poultry. Different types are to be found infesting various portions of the body, and so in the case of the fowl there are wing lice (*Lipeurus caponis*), body lice (*Eomenacanthus stramineus*), head lice (*Lipeurus heterographus*), fluff lice (*Goniocotes hologaster*), shaft lice (*Menopon allinae*).

Bird lice are wingless parasitic insects with the mouth parts adapted for biting. The latter feature is not generally appreciated as so many lice found on furred animals are blood suckers that popular opinion regards all lice as such.

Unlike ticks and mites, lice remain permanently on the host bird. Opportunity exists for transfer to other birds, however, per medium of crowded roosts, during copulation, while a hen is covering chickens or where infested and clean birds use the same nest.

Generally, each species of bird has its own species of lice, but if the two lots of birds are housed or running together, e.g., fowls and turkeys, one frequently finds the same species of lice on them both.

The damage done is due to irritation caused by their constant moving about on the bird and their feeding activities. As stated above they do not suck blood but eat the scales of the skin and the base of the feathers.

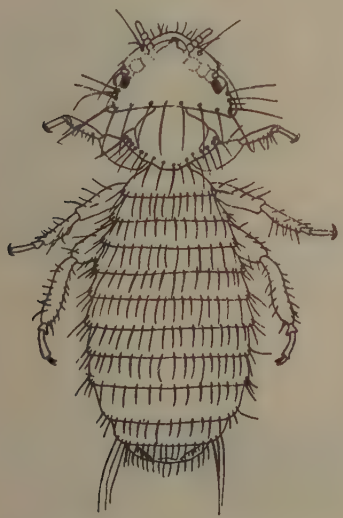

Fig. VII.
Female Body Louse (enlarged).
[After Herms.]

Fig. VIII.
Shaft louse (enlarged).
[After Giebel.]

Fig. IX.
Wing louse (enlarged).
[After Giebel.]

Fig. X.
Fluff louse (enlarged).
[After Denny.]

The effect of this on the bird need hardly be stressed, as it must reflect itself in a reduction in egg production, and, if the infestation is heavy, a loss of weight. It depends on the thriftiness of the birds as to what degree of infestation they can stand without showing the effects. Heavy infestations are generally associated with overcrowding and uncleanliness.

Life History.—In general, lice spend the whole of their lives on one host, except as mentioned above. The eggs are laid singly over a period of three weeks or so, and are attached to the base of the quills or on the feathers by a sticky secretion, and are popularly known as nits. The eggs are commonly seen in dense clusters, being greyish in colour. These eggs hatch in from 5-8 days and the young insects closely resemble the adults, but are of course smaller. After feeding they moult, i.e., shed their skins and increase in size. This process is repeated several times during a period of 3-4 weeks, at the end of which time they are fully grown. The adult is a small elongated, flattened insect and in the case of the body louse, about $\frac{1}{8}$ inch long. The general colour is greyish, sometimes with black marking. The six legs are provided with special claws to facilitate the insect running amongst and clinging to the feathers of the host. The mouth parts are on the under surface of the head.

CONTROL.

The most satisfactory agent for the destruction of the biting lice of poultry is powdered commercial sodium fluoride. This may be applied by the "pinch" method, the bird being held on a table over a dish or sheet of paper. A pinch of the powder is placed next to the skin under the feathers in each of the following places:—Under the head, on the neck, around the vent, on the tail, on each leg, on the breast, on the under surface of each spread wing and in two places on the back. The operator should use a handkerchief tied over the mouth and nose to stop inhaling the irritating dust.

Another easy and straightforward method of control is to paint the perches about half an hour before the fowls go to roost with undiluted black leaf 40 at

the rate of $^1_2$ ounce to each 100 feet of roost. The fumes which rise from this kill the lice on the birds.

With head lice, particularly in the case of chickens, applications of a non-irritating oil such as castor oil or neatsfoot oil should be applied directly to the affected area.

Dust baths are also useful and should be available to the birds. If fine ashes and a little sulphur are added to the dust the efficiency of the bath will be improved. Male birds, however, do not always avail themselves of these baths and should be treated by the sodium fluoride method, as they can be the means of spreading lice. A thorough spraying of the perches with kerosene emulsion is also recommended.

Fowl Stick-fast Flea (*Echidnophaga gallinacea* Westw.).

This serious pest of poultry was first recorded in Western Australia at Geraldton on native animals in 1913, but it was not until 1920 that it was first noticed in the metropolitan area as a pest of poultry.

Hosts.—The hosts of the stickfast flea are extremely numerous. The pest has been found attacking all poultry and many other birds, also dogs, cats, horses, rabbits and numerous native animals, and even man himself.

Fig. XI.
Stickfast Flea (enlarged).
[After Mönnig.]

Fig. XII.
Larva of Stickfast Flea (enlarged).
[After Campbell.]

Fig. XIII.
Head of fowl heavily infested with "Stickfast."
[After Newman & Allman.]

Description.—The stickfast flea is light brown to brownish black in colour, the male being smaller and darker than the female. Both are smaller than the common dog and cat fleas, and are characterised by the fact that they attach themselves to their host, bury their mouth parts into an exposed spot and remain there for the rest of their life. A favourite place is on the head of a bird, which may become literally black with fleas, but at moulting time they may also be found on the breast, under the wings and around the vent.

The effect of the flea on the bird is to weaken it from loss of blood. In heavy infestations the anaemic condition of the bird is indicated by the pale comb. Adult fleas have been known to live three months without a host.

Life History.—The complete life cycle takes about four weeks, varying according to the temperature. The female fleas lay at night while attached to the bird, and the eggs fall to the ground. The eggs are minute white objects from which in about four days a small worm-like creature emerges. This feeds on organic material, principally the dried blood excreted by the adult fleas, and shelters in the surface dust and litter on the soil. After several moults it grows to a length of about $\frac{1}{8}$ inch, ceases to feed and burrows down into the soil to a depth of about six inches. Here it spins a silken cocoon within which it develops into an adult flea. This last stage occupies about two weeks, then the adult flea emerges, burrows its way to the surface and searches for a host.

CONTROL.

All new birds and animals should be examined in order to prevent the introduction of the flea. Fleas may be controlled by smearing the infested parts with any non-burning oil such as neatsfoot or castor oil. The floors of the fowl houses should be made of concrete or other hard substance so as to facilitate the removal of all droppings and infested litter. If floors are thoroughly cleaned once a week the development of the immature fleas will be prevented, and any infestation quickly controlled. Exposure of the cleanings on a hot sunny day will kill the eggs and larvae. Where the flea has become well established, in addition to cleaning, the floor may be sprayed with creosote, sump oil, or kerosene emulsion.

Control measures against adults on the birds and larvae on the floor should be carried out simultaneously.

SUMMARY.

(i) The principal external parasites of poultry in Western Australia are:—

(a) Fowl tick.
(b) Poultry red mite.
(c) Scaly leg mite.
(d) Depluming mite.
(e) Lice.
(f) Stickfast flea.

(ii) Examine for parasites all newly acquired birds before they are allowed to mingle with other poultry.

(iii) Spray infested houses with creosote, sump oil, or kerosene emulsion.

(iv) Treat lice infested birds with sodium fluoride.

(v) Treat scaly leg mite, depluming mite, and seed tick with kerosene-lard sulphur ointment.

(vi) Control stickfast fleas by providing concrete floors under all hen roosts and cleaning up thoroughly once a week. Treat infested birds with any non-irritant oil.

APPENDIX.

Kerosene emulsion—stock solution:—

½ lb. soap.
1 gallon water.
2 gallons kerosene.

Dissolve the soap in the boiling water. Remove from fire and add the kerosene, at the same time agitating the solution for 10 minutes at least with a spray pump or syringe pump. Dilute as directed with warm water, and agitate as this assists in obtaining a stable mixture.

Creosote and crude oil emulsion are made in the same way, substituting these for the kerosene in the formula.

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Pasture Development.

Part 1.

Species Trials, 1936-1940.

H. G. ELLIOTT, Agrostologist.
F. E. RYAN, Field Technician.

CONCLUSIONS.

Carrying Capacity.

(1) During the year of establishment the carrying capacity of small areas sown with the pasture species mentioned was 1.46 acres per cow.

The individual plots for the same period carried—

Perennial rye grass and white clover, 1 cow to 1.66 acres.
Cocksfoot and white clover, 1 cow to 1.78 acres.
Phalaris tuberosa and white clover, 1 cow to 1.86 acres.
Tall fescue and white clover, 1 cow to 0.96 acres.

(2) Over the five year period from establishment, Phalaris tuberosa and perennial rye grass carried slightly more stock than cocksfoot and tall fescue.

(3) Over the last three years of the experiment, 1938, 1939, and 1940, all species have become established and the grazing obtained during these years may be taken as the grazing capacity of the pastures over long periods as permanent pastures. Perennial rye grass and Phalaris tuberosa were the outstanding species carrying one cow to 0.7 acres and 0.68 acres respectively.

(4) With maturity of the various species this carrying capacity is more evenly spread over the whole year.

Comparison of Species.

(1) The tall fescue-white clover field was outstanding during the establishment year in providing the greatest amount of grazing. The other three species were approximately similar in production.

(2) As permanent pasture the Phalaris tuberosa-white clover and the perennial rye grass-white clover mixtures were superior.

(3) Tall fescue reaches its maximum development after the first year. Cocksfoot required two years to reach a maximum but Phalaris tuberosa and perennial rye grass require three years to reach maximum development.

(4) Phalaris tuberosa and perennial rye grass provided more winter grazing than did the other two species and Phalaris tuberosa was somewhat superior to perennial rye grass in this respect.

Yield in tons per acre.

(1) The main results obtained from examination of the grazing figures were confirmed by the yield figures from the cuts.

(2) The average production in tons per acre over four years was 35.22 tons of green material per annum.

(3) The carrying capacity over the same period was 472.95 grazing days per acre, thus making 1 ton of green material equivalent to 13.4 cow grazing days per acre.

(4) The yields of Phalaris tuberosa and perennial rye grass over the four-year period were highest whilst that of cocksfoot and tall fescue were lower. The yields are given in Table 7.

INTRODUCTION.

The State Committee of the Australian Dairy Council decided to co-operate with the Department of Agriculture in, and made funds available for, conducting an experiment on the property of Mr. C. Henning, of Hamel. The experiment was conducted with a view to showing the value of various grass species under controlled grazing in the irrigation areas. Preparations were made during 1935, and the area was sown down in November, 1935.

AIM AND OBJECTS.

The objects of the experiment were:—

(1) To determine the most suitable grass species in association with white clover for establishment of a permanent pasture under irrigated conditions, on a soil type selected in this irrigation area.

(2) The collection of information regarding the carrying capacity of pastures on small irrigated areas.

(3) To determine the yields per acre of green material of various species under existing conditions.

MATERIALS AND METHODS.

An area of 10 acres was selected. This was divided into five plots of two acres each with a central race connecting paddocks. The land was taken over in August, 1935. It had been under a summer crop of potatoes, prior to that it was under pasture consisting mainly of subterranean clover, drooping flowered clover, paspalum, and couch grass.

Soil.

The soil consists of a deep chocolate loam which had not been efficiently drained. It originally carried bluegum timber. Owing to lack of efficient consolidation of the soil it was too soft during the winter months to allow of grazing by dairy stock.

Cultivation.

The land was ploughed to a depth of 6 inches during October, left for two weeks then worked down and rolled to consolidate the seed bed.

Seed mixture.

The plots were sown down to various pastures in November, 1935, following an irrigation early in that month.

The following seed mixtures were sown:—

Plot 1.—New Zealand certified mother strain perennial rye grass 8 lb., and New Zealand certified white clover 2 lb. per acre.

Plot 2.—New Zealand certified Akaroa cocksfoot 10 lb. plus New Zealand certified white clover, 2 lb. per acre.

Plot 3.—Certified Phalaris tuberosa 4 lb. plus New Zealand certified white clover 2 lb. per acre.

Plot 4.—New Zealand tall fescue 8 lb. plus New Zealand certified white clover 2 lb. per acre.

FERTILISER.

The rate and time of application of fertiliser are shown in table form below:—

	1936.		1937.		1938.		1939.		1940.	
1st Application ...	super. per acre. 150 lbs. + 70 lbs. Sulph. Ammonia	Nov. 27, 1935.	super. per acre. 320 lbs.	Mar. 30	super. per acre. 212 lbs.	Feb. 2	super. per acre. 224 lbs.	Feb. 12	super. per acre. 112 lbs.	Feb. 12
2nd Application ...	2 cwt.	Nov. 15	180 lbs.	Sept. 27	112 lbs.	Sept. 12	224 lbs.	May 10	224 lbs.	May 10
3rd Application ...	...	...	...	...	112 lbs.	Nov. 14	224 lbs.	Sept. 17	224 lbs.	Sept. 21
Total	374 lbs. + 70 lbs. Sulph. Ammonia	...	500 lbs.	...	436 lbs.	...	672 lbs.	...	560 lbs.	...

IRRIGATION.

The irrigation table is given below:—

——	1936.	1937.	1938.	1939.	1940.
1st Irrigation	Jan. 7	Jan. 13	Jan. 7	Jan. 21	Jan. 11
2nd Irrigation	Feb. 5	Feb. 13	Feb. 11	Feb. 11	Feb. 15
3rd Irrigation	Mar. 7	Mar. 13	Dec. 1	Nov. 24	Nov. 21
4th Irrigation	Dec. 15	Dec. 1	Dec. 25	Dec. 17	Dec. 14

GERMINATION AND GROWTH.

Germination on all plots was very good in 1935.

Plot 1.—During 1936 perennial rye grass was not completely thrifty but there was a good cover of the grass. Couch grass was well established and inhibited the successful establishment of the sown pasture plants.

Plot 2.—White clover made rapid establishment, but cocksfoot, although good germination was obtained, had not thickened up sufficiently to make a good stand. Here again couch grass had a retarding effect on rapid establishment.

Plot 3.—Excellent germination of both species was obtained but generally growth was poor on account of lack of efficient fertiliser during the wet months of the year. After topdressing and with the event of hot weather better growth was obtained.

Plot 4.—Both tall fescue and white clover made excellent growth during the 1936 season, the fescue doing exceptionally well during the winter months. Couch grass also made considerable growth during the season but was checked to a considerable extent by white clover and grazing towards the end of the year. Dodder affected the growth of white clover in plots 1 and 4. Heavy grazing of these plots during October checked the flowering and seeding considerably.

GRAZING.

Grazing commenced in February, 1936. The method of grazing was to turn a large number of stock on to a paddock for a short period of one or two days of eight hours each and then spell the paddock for a fortnight or three weeks.

SAMPLING.

Sampling was carried out at monthly intervals, where the growth warranted a cut being made. Three cuts were made per plot from under wire cages which prevented the stock reaching the pasture during grazing.

RENOVATION.

After the preparation of the seed bed in 1935 no renovation was carried out during the establishment year in 1936.

During 1937 renovation with ordinary harrows was carried out on March 29th.

During 1938 complete renovation with rotary prong type of renovator followed by zig-zag and chain harrows combination, was carried out on 27th July. A thorough aeration and breaking up of droppings was obtained.

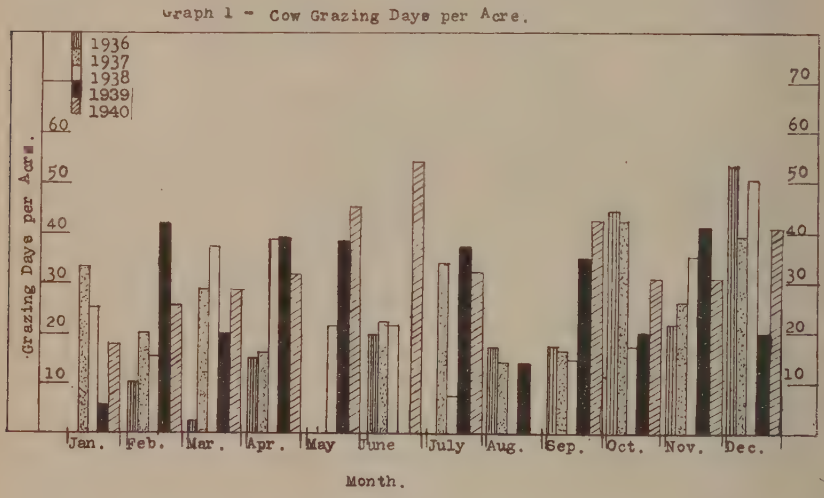
On 19th August, the irrigation furrows were cleared out with a "Sunbuster" plough and spoil broken down with disc cultivator and T bar roller.

On 25th July, rushes were slashed and on November 10th, most of them were grubbed out.

In 1939 no further renovation was necessary but the rushes were further controlled.

RESULTS.

Grazing.



Graph 1 shows "Grazing Days per Acre" obtained per month from the whole area for five years. From this graph it will be seen that the periods when most grazing is obtained is during the spring, late autumn period. July is the month in which least grazing is obtained during the first year, but grazing in this month has increased markedly over the last four seasons. The last two years show a more even monthly grazing figure due to improvements in management of the pastures and full establishment of the species.

TABLE 1.

CARRYING CAPACITY FROM WHOLE AREA.

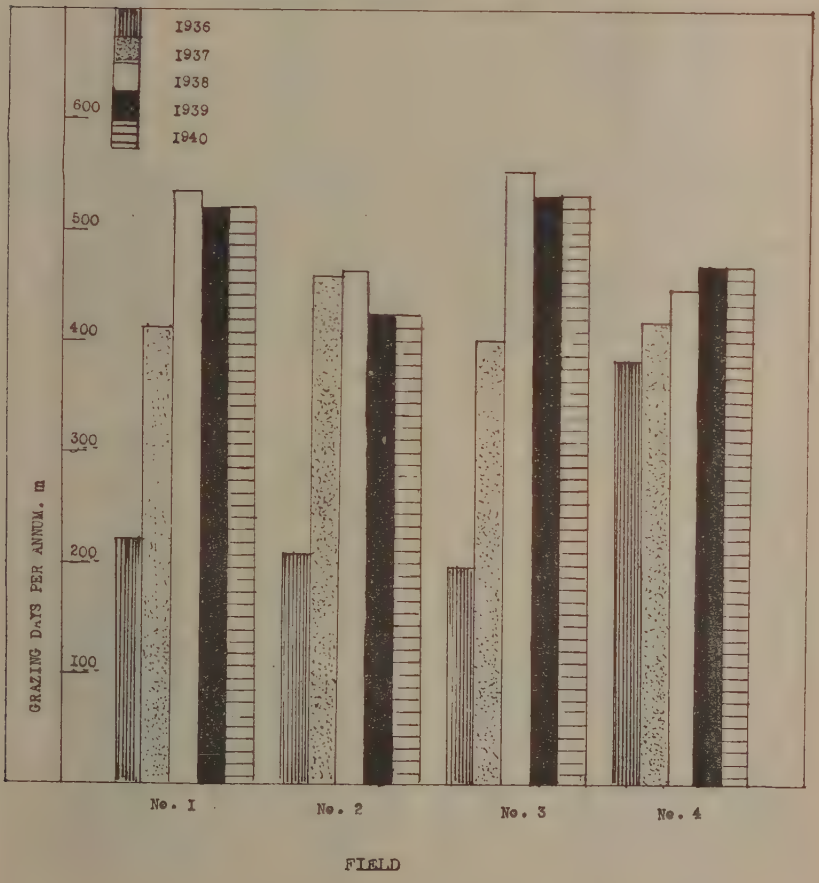
Year.	Grazing Hours.	Total Grazing Days.	Grazing Days per Acre.	Acres per Cow.
1936	16,504	2,063	250	1·46
1937	28,680	3,585	434·5	0·84
1938	32,957	3,990	499	0·73
1939	33,328	4,166	508	0·72
1940*	33,328	4,166	508	0·72

* During 1940 the same grazing programme as 1939 was used, but two cuts with the mower had to be made in the spring and summer, and consequently more stock could have been carried during 1940.

Average carrying capacity over the last four years has been very constant and approximately 0.75 acres per cow.

Table 1 gives the carrying capacity each year over the five-year period. The carrying capacity increased rapidly between 1936-37 and 1937-38 and for the three years, 1938, 1939 and 1940, has remained remarkably constant at 0.723 acres per cow.

Graph 2 - COW GRAZING DAYS (8 hours) PER ACRE.



Graph 2 shows the number of "Grazing days per Acre" for each of the species. Tall fescue (field 4) produced more grazing than any other plot in 1936 but has only given slight increase since. Field 2 (cocksfoot) gave highest grazing in 1937 and remained fairly constant at that figure. Field 3 (Phalaris tuberosa) steadily

increased to give most growth in 1938, then decreased slightly during next two years. Field 1 (perennial rye grass) was very similar to field 3 in that it reached its highest peak in 1938 and decreased slightly in next two years.

The total grazing is given in Table 2.

TABLE 2.

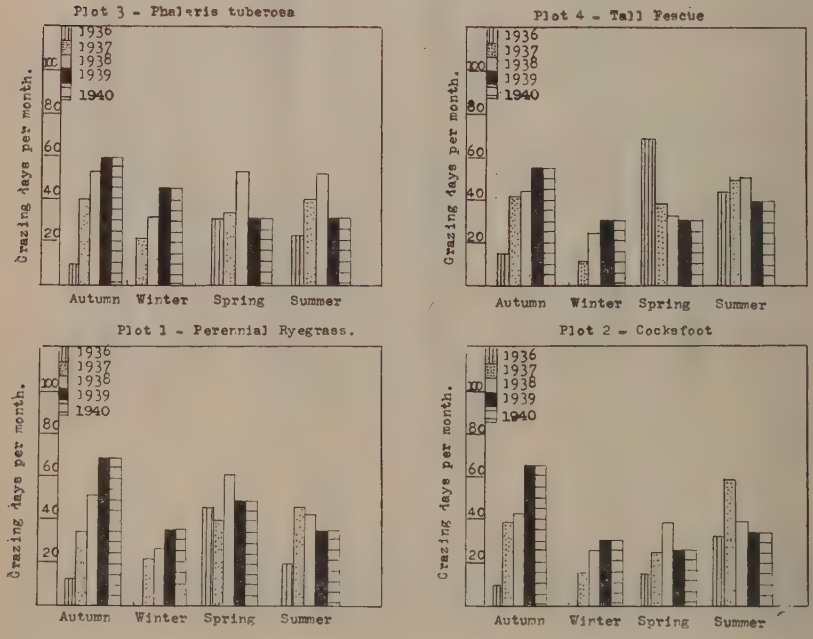
TOTAL NUMBER OF COW-GRAZING DAYS PER MONTH FROM EACH FIELD OVER 5-YEAR PERIOD.

Field.	Cow-grazing Days per Month.
Field 1	38·5
Field 2	33·8
Field 3	37·4
Field 4	35·8

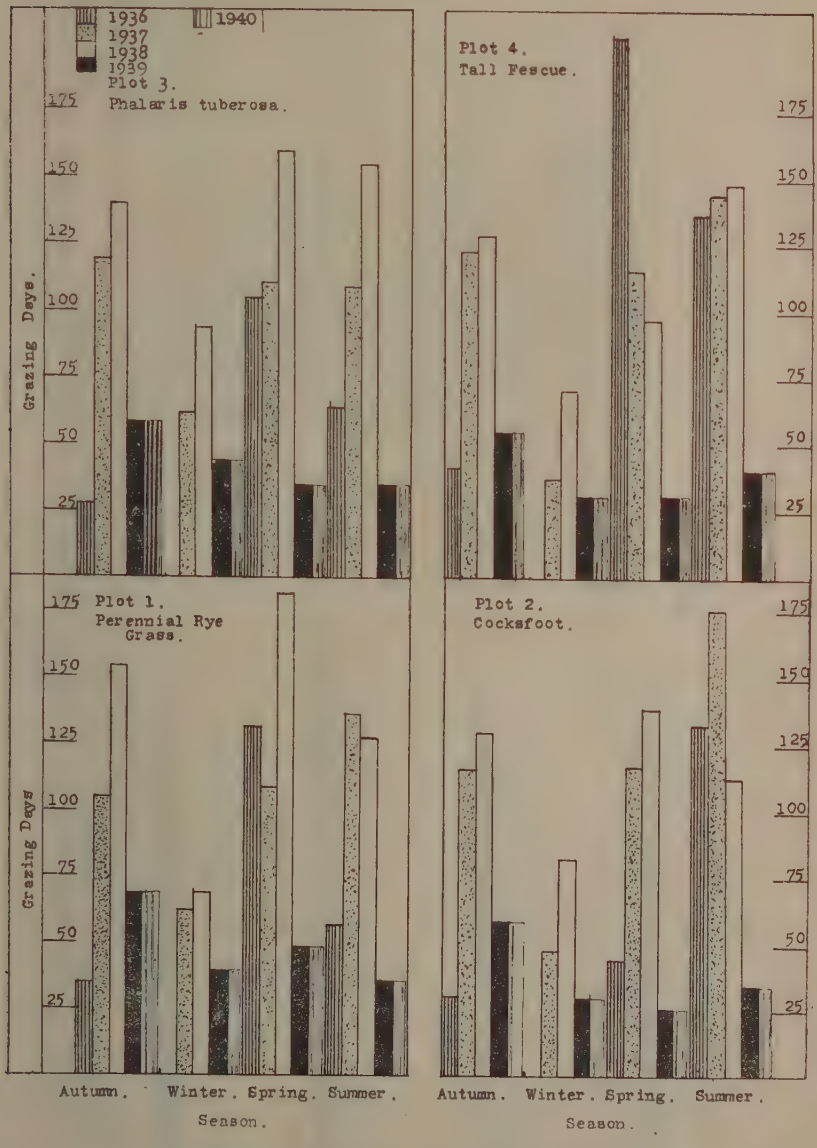
It will be seen that over the five-year period perennial rye grass-white clover and Phalaris tuberosa-white clover gave most grazing. During 1938, 1939 and 1940 the order of superiority was Phalaris tuberosa, perennial rye grass, cocksfoot and tall fescue.

Graphs 3 and 3A give the quarterly "seasonal grazing" figures from each of the plots.

Graph 3 . Three-monthly Seasonal Grazing Days for Four Fields .



Graph 3A - Three-Monthly Seasonal Grazing Days for the Four Fields.



The autumn production of these fields increased steadily in successive years. Best production was obtained from field No. 1 (perennial rye grass) and field 3 (Phalaris tuberosa). A steady increase occurred on all fields during the winter months, the greatest amount of grazing being obtained from field 3. All fields except field 4 (tall fescue) increased in spring production and field 4 decreased slightly.

Table 3 gives the cow grazing days per acre in each field.

TABLE 3.

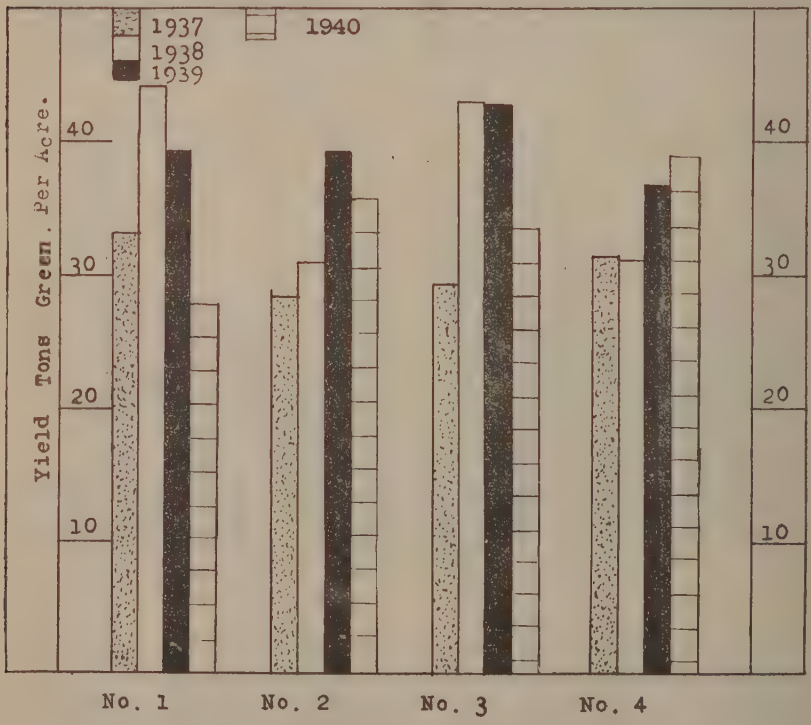
COW-GRAZING DAYS PER ACRE ON EACH FIELD.

Year.	Field 1.	Field 2.	Field 3.	Field 4.
1936	220·6	205·7	195·9	381·0
1937	410·6	457·25	399·25	416·9
1938	534·5	460·9	552·5	447·3
1939	520·2	422·6	531·0	467·7
1940	520·2	422·6	531·0	467·7
Average for five years ...	441·2	403·8	441·9	436·1
Average for 1938–39–40 ...	525·0	435·4	538·2	460·9

YIELDS.

Graph 4 gives the annual production of green materials per acre from each of the four fields.

Graph 4 Annual Production in Tons for the Four Fields.



The yields increased during 1938 and 1939, but decreased again in 1940.

Fields 1 and 3 gave the highest total yields.

TABLE 4.

ANNUAL PRODUCTION IN TONS PER ACRE.

Year.	Tons per Acre.
1937	30.5
1938	37.2
1939	40.0
1940	33.9

Table 4 gives total annual production per acre over the four years. The increase up to 1939 and the decreases in 1940 will be noted. The total production for the August to December period and the total annual production on each field are given in tables 5 and 7.

TABLE 5.

PRODUCTION ON EACH FIELD FOR THE PERIOD AUGUST TO DECEMBER.

Year.	Field 1.	Field 2.	Field 3.	Field 4.
	tons per acre.	tons per acre.	tons per acre.	tons per acre.
1936	12·7	11·1	10·6	8·1
1937	17·7	14·1	15·2	15·8
1938	23·9	17·9	22·9	15·8
1939	19·5	19·6	19·5	17·6
1940	10·75	15·34	13·34	15·56
Average	16·91	15·61	16·31	14·57

TABLE 7.

TOTAL PRODUCTION IN TONS PER ACRE FROM EACH OF THE FOUR FIELDS.

Year.	Field 1.	Field 2.	Field 3.	Field 4.
1937	32·887	27·683	29·420	31·36
1938	44·15	31·01	43·03	31·15
1939	39·0	39·0	43·0	37·0
1940	27·43	35·35	33·23	38·82
Total	143·467	133·043	148·68	138·33

Average Annual Production—35·22 tons green material.

The superiority of fields 1 and 3 may be seen.

Table 6 gives the seasonal yields each year. It will be seen that there is an increase in winter production, except for 1939, over the 1937 figure.

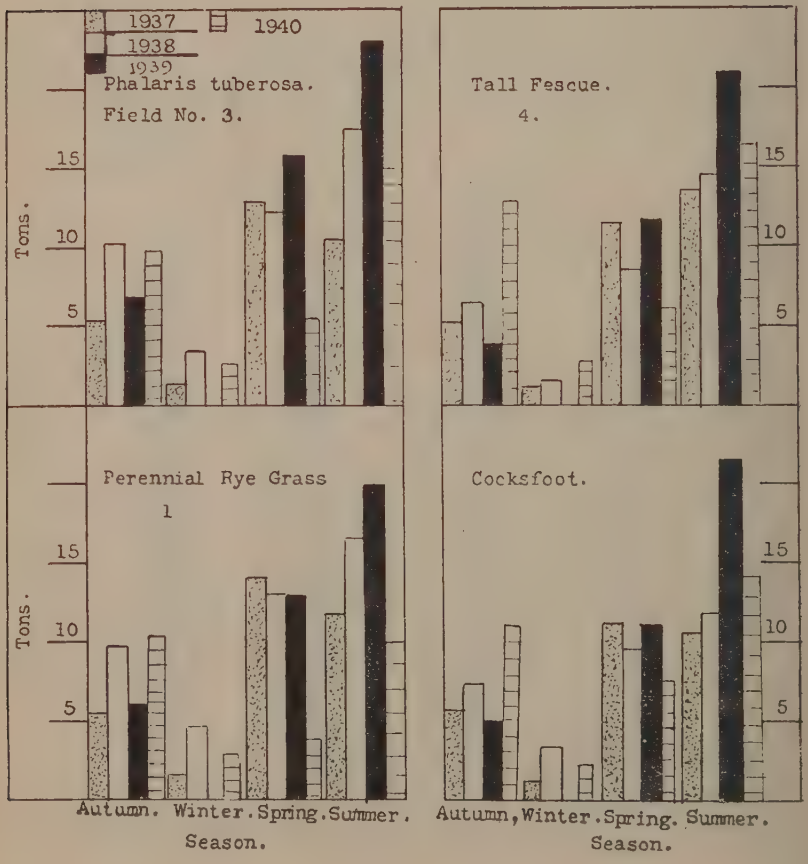
TABLE 6.

THREE-MONTHLY YIELDS FROM ALL FIELDS FOR THE FOUR SEASONS.

Year.	Autumn.	Winter.	Spring.	Summer.
	tons per acre.	tons per acre.	tons per acre.	tons per acre.
1937	5·3	1·3	12·6	11·3
1938	8·4	3·2	10·9	14·7
1939	5·5	...	13·0	21·5
1940	10·9	2·7	5·8	14·3
Average	7·5	1·8	10·6	15·45

Graph 5 shows graphically the three-monthly yields of each of the fields. The highest winter production has occurred on field 1.

Graph 5 - Three-Monthly Seasonal Yields for the four Fields.



DISCUSSION.

1. *Carrying Capacity.*

A summary of the grazing over the whole experimental area for the five years of the experiment is given in table 1. During the year of establishment (1936) the four plots carried an average of one milking cow to 1.46 acres. This increased during 1937 to one cow to 0.84 acres and then during 1938, 1939, and 1940 increased to and remained constant at the figure of one cow to 0.72-0.73 acres, with an average for the three years of one cow to 0.72 acres. A closer examination of the results indicates that even this figure can be improved upon by the choice of the best species. Thus when fully established, perennial rye grass during 1939 and 1940 gave 574.3 days of grazing per acre. The average for the whole four plots during the same years was 505.6 cow grazing days. That is, the rye grass white clover plot carried one cow to 0.64 acres. This high carrying capacity was only reached after an establishment period had elapsed. The carrying capacity during 1936 was only half of that achieved during the years 1938, 1939 and 1940.

The figure 0.72 acres per cow per annum is a barren figure unless the grazing is well distributed throughout the year. The figures during the first year (1936) were very uneven, the greatest amount of grazing being obtained during the months of October, November and December, but when all species had become well established there was a rise in the autumn and especially in the winter production and a decrease in the spring and summer production. From graph 1, the evenness of growth during 1939 and 1940 is apparent. Thus the high carrying capacity has been achieved along with evenness of grazing production throughout the months of the year. An examination of graph 3 shows that this factor is also dependent to some extent on the species in the pasture mixture and in this case the grazing obtained from the Phalaris tuberosa field was greatest of all four fields. With the choice of the best species (in this case perennial rye grass and Phalaris tuberosa) more even grazing could have been obtained throughout the year.

The production of green material from the plots does not coincide exactly with the grazing figures but the main tendencies are apparent in each. Thus during 1938 and 1939 highest production was obtained from fields 1 and 3 (see graph 4). Similarly fairly good production was recorded for the winter production on the perennial rye grass and Phalaris tuberosa fields. The discrepancies which do occur are due to several reasons such as the fact that the grazing was carried out when the plots required grazing, but the cuts were made at monthly intervals or at longer intervals if sufficient material was not available for cutting. Also the paddock could be grazed even when production was low whereas it was only cut when the production reached sufficient height. Again cuttings were made on areas which were protected from stock for periods of from 1 month to 3 months and such plants as cocksfoot reaped an advantage therefrom.

However, the main observations from the production of green material per acre, are in agreement with these obtained from grazing figures.

2. *Comparison of Species.*

From graph 2 it is obvious that during the first year (1936) the tall fescue-white clover field was outstanding in producing 85 per cent. more grazing than any of the other three fields. On this field an excellent first year establishment was

obtained and excellent growth obtained during the first year. Subsequent increases in grazing were only slight and may be summarised as follows:—

1937	.. .. ..	9% increase over 1936
1938	.. .. ..	7% increase over 1937.
1939	.. .. ..	4% increase over 1938

Tall fescue, then, reaches its full development very rapidly and has almost reached maximum production after one year.

Perennial rye grass and white clover (field 1) also obtained a good initial establishment but growth during the first year was slow and full development and growth were only reached during 1930-40. Subsequent increase since 1936 may be summarised as follows:—

1937	.. ..	an increase of 86% over 1936
1938	.. ..	an increase of 30% over 1937
1939	.. ..	a decrease of 3% over 1938

The Phalaris tuberosa and white clover (Field 3) achieved a poor first year establishment but produced equally well with perennial rye grass in the first year. The figures for this field are as follows:—

1937	.. ..	an increase of 103% on 1936
1938	.. ..	an increase of 38% on 1937
1939	.. ..	a decrease of 4% on 1938

Thus Phalaris tuberosa also took a considerable period before maximum production was reached.

Cocksfoot (Field 2) also was poorly established in the first year but provided almost as much grazing as did perennial rye grass and Phalaris tuberosa. It had almost reached maximum development by the end of 1937 and subsequent increases were only slight and may be summarised as follows:—

1937	.. .. ..	122% increase on 1936
1938	.. .. ..	1% increase on 1937
1939	.. .. ..	8% decrease on 1938

From these figures we can gather the difference in behaviour of the four species. The tall fescue grows rapidly in its first year and has reached almost maximum development after its first year. Cocksfoot after making phenomenal growth in the second year was almost fully developed by the end of 1937 whilst Phalaris tuberosa and perennial rye grass did not reach maximum production until the end of 1938.

From the total grazing figures for the five years, perennial rye grass and Phalaris tuberosa provided most grazing whilst tall fescue was almost equal to them A more important figure is that obtained over the last three years. By this time (1938, 39 and 40) all species had become well established and would be expected to provide a similar amount of grazing for a number of years to come. These figures show that Phalaris tuberosa and perennial rye grass were the superior species and that they carried about 25% more grazing than did cocksfoot and tall fescue.

Finally it is important in any pasture mixture that the grazing be fairly evenly distributed throughout the year. In this respect the winter period is usually the critical period of the year for farmers. Both Phalaris tuberosa and perennial rye grass fields show the highest winter grazing figures and in this respect Phalaris tuberosa is somewhat superior to perennial rye grass. See graphs 3 and 3A.

The results obtained from the yields of green material (graphs 4 and 5) confirm these conclusions in the main. Phalaris tuberosa and perennial rye grass are again the superior species and superior in winter production.

3. *Yield in Tons per Acre.*

Yields in the form of cuts of green material were obtained only over the last four years of the experiment.

A comparison of the yields in tons per acre from individual plots and the grazing figures for these plots show some discrepancy due to a number of factors, already enumerated.

The average annual production of the four-year period, 1937, 38, 39 and 40, was 35.22 tons green material per acre. The average number of cow grazing days per acre for the same period was 472.95. Over the four years, 1937, 38, 39 and 40, one ton of green material per acre was equivalent to 13.4 cow grazing days per acre. Over the 3 years, 1938, 39 and 40, one ton green material per acre was equivalent to 13.5 cow grazing days per acre.

Thus we may take one ton of green material per acre as equivalent to 13.4 cow grazing days. The yields of Phalaris tuberosa, and perennial rye grass over the four year period were highest whilst that of cocksfoot and tall fescue were less. This is in confirmation of the grazing results.

Phalaris tuberosa yielded 148.68 tons of green material per acre over the four-year period with an average of 37.17 tons per acre per annum. Perennial rye grass yielded 143.467 tons of green material per acre over the four-year period with an average of 35.87 tons per acre per annum. Cocksfoot yielded 133.043 tons per acre over the four-year period with an average of 33.26 tons per acre per annum. Tall fescue yielded 138.33 tons per acre over four years with an average of 34.58 tons per acre per annum.

Part 2.

CONCLUSIONS.

A. *Carrying Capacity.*

(1) During the establishment year the carrying capacity of small areas, sown down with the pasture species mentioned, in this particular soil and climatic environment was one cow to 1.8 acres.

(2) Over the five-year period from establishment, Phalaris tuberosa and white clover carried most stock, but very little more than tall fescue and white clover, paspalum and white clover and a mixture of paspalum and perennial rye grass and white clover. Perennial rye grass and white clover alone provided least grazing of all plots for reasons given below.

(3) Over the last three years which may be taken as the grazing provided from each pasture mixture as a permanent pasture, the paspalum-perennial rye grass, and white clover mixture was superior whilst tall fescue and white clover, Phalaris tuberosa and white clover and paspalum and white clover were slightly less successful. Perennial rye grass and white clover was least successful.

B. *Comparison of Species.*

(1) Phalaris tuberosa and white clover provided most grazing in the establishment year, closely followed by tall fescue and white clover.

(2) As permanent pasture in this area under the existing conditions, Phalaris tuberosa and white clover and a combination of paspalum and perennial rye grass and white clover proved superior.

(3) Phalaris tuberosa and white clover provided the greatest amount of winter grazing, but not very much more than tall fescue and white clover and the perennial rye grass-paspalum and white clover combination.

C. *Yield.*

(1) The average production in tons per acre over four years, 1937-40, was 19.1 tons.

(2) The carrying capacity for the four years, 1937-40, was 328.0 cow grazing days per acre per annum. Hence one ton in production is equivalent to 17 cow grazing days.

(3) The yields of Phalaris tuberosa and white clover and the paspalum and white clover were greatest of the five plots.

INTRODUCTION.

During 1935 the State Committee of the Australian Dairy Council made funds available for initiating demonstrations under irrigated conditions with a view to showing the value of various grass species under controlled grazing. The State Committee decided to co-operate with the Department of Agriculture in establishing two experimental areas on the properties of Messrs. J. Neil, Waroona, and C. H. Henning, Hamel.

A separate report has been prepared for the experiment conducted at C. H. Henning's property and the experiment conducted on the property of J. Neil is analysed hereunder.

AIM AND OBJECTS.

(1) To determine the most suitable plants for establishment of permanent pastures under irrigated conditions on a soil type selected in this irrigation area.

(2) The collection of data regarding the carrying capacity of these pastures on small irrigated areas.

(3) To determine the actual yield per acre from the various mixtures under existing conditions.

MATERIALS AND METHODS.

An area of 12.94 acres was selected and divided into five fields and a race. The area of fields 1, 2, 4, and 5 was 2.39 acres each and field No. 3 was 2.5 acres. This area was taken over in 1935 and had previously carried a pasture consisting mainly of subterranean clover and couch grass (Cynodon dactylon) but had a very heavy infestation of Guildford grass (Romulea rosea) and also Dodder (Cuscuta spp.).

Soil.

The soil consists of a greyish sandy loam overlying a yellow clay situated on a plain three miles west of Waroona. The area had a tendency to become waterlogged in winter and showed evidence of salt during the summer. The original timber was red-gum and jarrah and numerous blackboys.

Fertiliser.

The details of the fertiliser programme are given in table form below.

	1936.		1937.		1938.		1939.		1940.	
1st Application ...	super. per acre. 150 lb. + 70 lb. Sulph. Ammonia	Oct. 14 (1935)	super. per acre. 180 lbs.	Jan. 24	super. per acre. 224 lbs.	Feb. 26	super. per acre. 224 lbs.	Jan. 23	super. per acre. 224 lbs.	Jan. 20
2nd Application ...	170 lbs.	March	180 lbs.	April 8	224 lbs.	May 9	224 lbs.	May 24	224 lbs.	May 26
3rd Application ...	300 lbs.	April	180 lbs.	Sept. 2	224 lbs.	Sept. 10	224 lbs.	Sept. 14	224 lbs.	Sept. 10
4th Application ...	300 lbs.	September	180 lbs.	Dec. 11						

Cultivation.

During 1935 the land was ploughed to a depth of four inches and allowed to remain fallow for four weeks. It was cross ploughed in September and thoroughly cultivated to prepare a well worked firm seed bed. Seed was sown in the middle of October and lightly rolled in.

Seed Mixtures.

Seeding was carried out in the middle of October, 1935, and the following mixtures were sown. In each case certified New Zealand white clover was incorporated at the rate of 2 lbs. per acre.

Plot 1. -New Zealand certified mother strain perennial rye grass, 8 lbs. per acre.

Plot 2.—New South Wales Paspalum dilatatum, 10 lbs. per acre.

Plot 3.—New Zealand certified perennial rye grass, 4 lbs. per acre. New South Wales Paspalum dilatatum, 4 lbs. per acre.

Plot 4.—New Zealand tall fescue, 8 lbs. per acre.

Plot 5.—South Australian certified Phalaris tuberosa, 4 lbs. per acre.

Irrigation.

	1936.	1937.	1938.	1939.	1940.
1st Irrigation	Jan. 10	Jan. 8	Jan. 12	Jan. 24	Jan. 4
2nd Irrigation	Feb. 6	Feb. 4	Feb. 7	Feb. 20	Jan. 25
3rd Irrigation	Mar. 1	Feb. 24	Feb. 28	Mar. 25	Feb. 17
4th Irrigation	Dec. 7	Mar. 22	Nov. 28	Nov. 1	Mar. 20
5th Irrigation	...	Nov. 16	Dec. 25	Dec. 10	...
6th Irrigation	...	Dec. 16	...	...	...

GERMINATION AND GROWTH.

The germination of all species was good but soon after germination a week of strong east winds prevailed which dried the surface rapidly and it was feared at first that reseeding might be necessary. However, further irrigations of which there were four showed that reseeding was not necessary although some reduction in stand did occur. During the year 1936, the condition of the plots was described as follows:—

Plot 1.—During the year there was good growth of perennial rye grass, but the cover of white clover was very light in places. Towards the latter part of the season white clover was showing better growth and covering the bare ground.

Plot 2.—This plot produced a very good stand of white clover and during the latter part of the season showed a decided thickening up of the paspalum. The initial establishment of this grass was seriously affected by the strong easterly winds which occurred after early germination.

Plot 3.—This plot contained a considerable amount of couch grass (*Cynodon dactylon*). The white clover produced excellent growth but the rye grass and paspalum took considerable time to thicken up.

Plot 4.—Both tall fescue and white clover grew vigorously and matted the surface well. The fescue was particularly vigorous during the winter months; although a coarse grass it is relished by grazing cows.

Plot 5.—An excellent germination of Phalaris tuberosa and white clover was obtained and both species grew vigorously producing most grazing for the first season.

General.

The white clover was affected during the winter months with dodder (*Cuscuta spp.*), but as soon as the land was firm enough to use blade harrows excellent control was obtained. Following the harrowing the plots were heavily grazed and harrowed a second time. During the latter part of the season excessive salt on the surface burnt back a considerable number of white clover plants. These however, revived after the first watering. There was also a heavy infestation of stinkwort which was controlled by mowing. Effective control was obtained.

A dam of 200 cubic yards capacity was excavated in a central position and connected to the various fields by a race. This could be filled when necessary with irrigation water to provide sufficient water for the grazing cows.

Grazing.

Grazing commenced in February, 1936. The method of grazing adopted was intermittent. A large number of animals were grazed on each paddock for a short period of one or two days. The paddocks were then spelled for three to six weeks.

Sampling.

Sampling was carried out at monthly intervals where growth warranted a cut being made. Three cuts were made per plot from under wire cages, which prevented stock reaching the pasture beneath during grazing. Following each cut the cages were shifted to a new site.

Renovation.

Before sowing the land was thoroughly ploughed and cultivated and after seeding, it was rolled.

During 1936, the whole area was double lapped with a sunblade pasture harrows in August. This greatly facilitated the control of dodder. A further harrowing was carried out six weeks later.

During 1937, cultivation with a sunblade pasture harrows was carried out in January and again in July. On each occasion the pasture was stroked twice.

During 1938, a harrowing was carried out with knife blade harrows on May 9. On July 25, severe renovation with a rotary prong type renovator double lapped and followed by pasture harrows was carried out. On the 30th September, irrigation furrows were cleaned out with a "Sunbuster" plough.

During 1939, the complete area was harrowed twice with blade type of harrows. Topping was carried out in January.

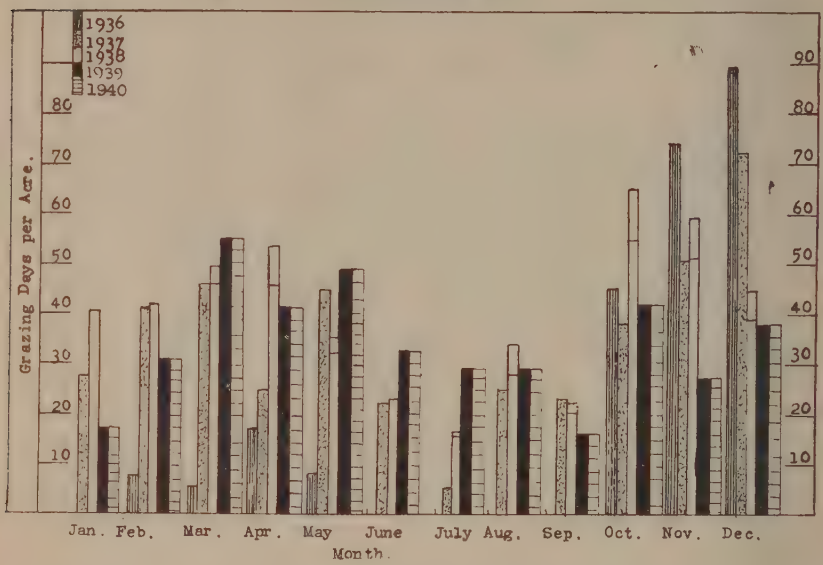
During 1940, a harrowing was carried out on 15th July.

RESULTS.

Grazing.

Graph 1 shows "grazing days per acre" obtained per month over the whole area for five years.

Graph 1 - Cow Grazing Days per Acre.



From this graph it will be noted that considerable amount of grazing was obtained during the winter months. The grazing was however, somewhat intermittent and spasmodic. This is demonstrated in graph 1A.

In this graph the grazing has been shown for each month of each of the five years.

Table 1 gives the carrying capacity over the 5-year period 1936-40 (inclusive).

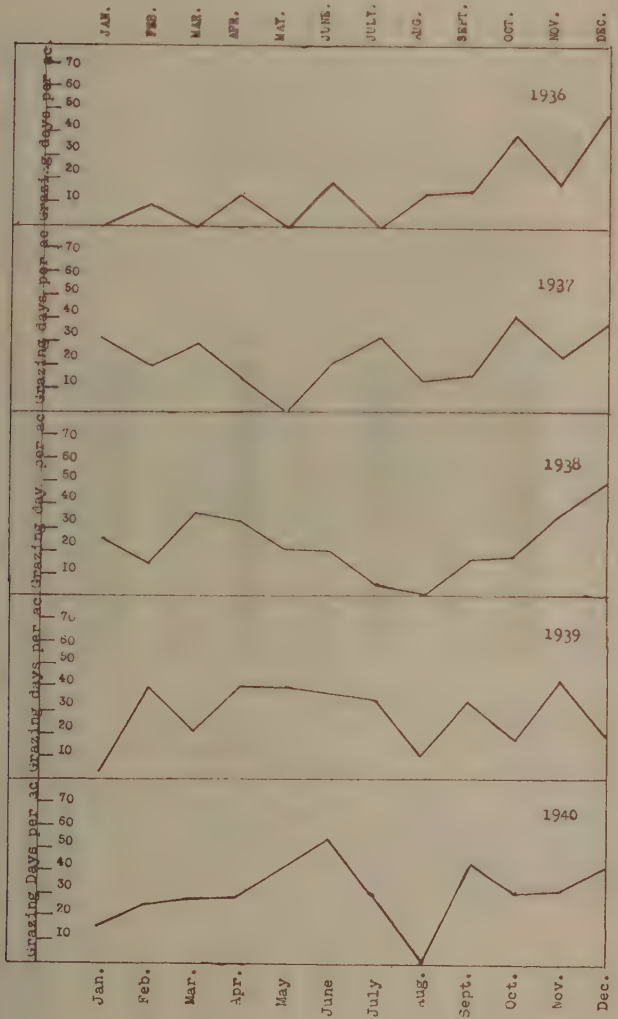
TABLE 1.

CARRYING CAPACITY OF THE AREA OVER FIVE YEARS.

Year.	Cow-grazing Hours.	Cow-grazing Days.	Cow-grazing Days per Acre.	Acres per Cow.
1936	20,952	2,619	203	1·80
1937	30,384	3,798	294·4	1·24
1938	29,891	3,736	285·8	1·28
1939	30,073	3,759	320	1·14
1940	38,183	4,773	398	0·91

The area carried 1 cow to 1.8 acres in the establishment year 1936, and carrying capacity increased during 1937 to 1 cow to 1.24 acres, Apart from a slight decline in 1938, the increase in the carrying capacity has continued to 1 cow to 0.91 acres in 1940. The average over the whole period is 1.27 acres per cow and over the last four years is 1.14 acres per cow.

Graph Ia - GRAZING DAYS PER ACRE FOR EACH YEAR.



The Phalaris tuberosa plot provided most grazing in the establishment year and perennial rye grass provided least. This was partly due to a rust attack and a low association of white clover and for reasons given above. During the second year all species showed improvement. During 1940, a substantial increase occurred on all plots especially plots 2, 3 and 5.

Table 2 summarises the grazing details on each of the plots over the five-year period.

Graph 2 shows the number of cow grazing days per acre for each specie.

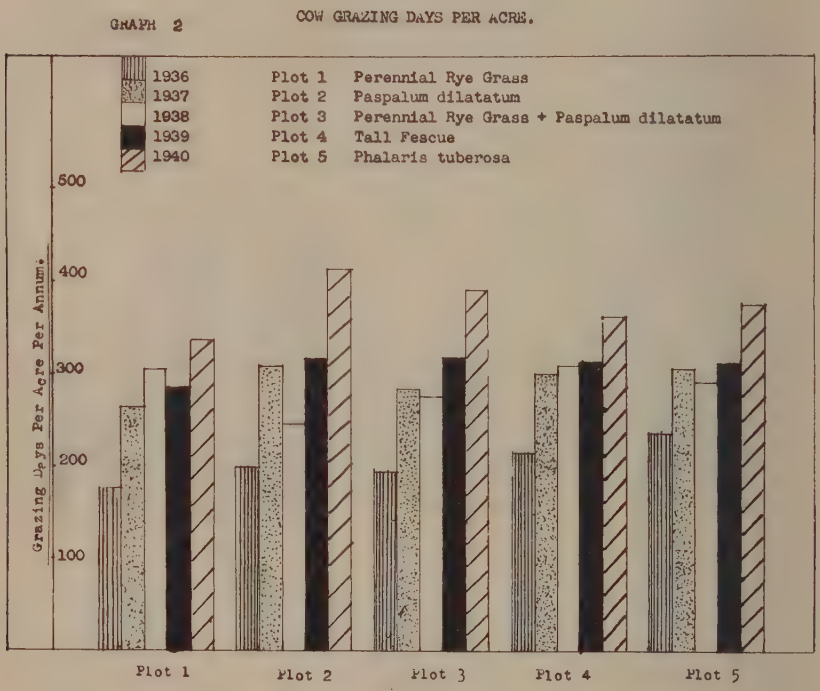


TABLE 2.

COW GRAZING DAYS PER ACRE ON EACH PLOT.

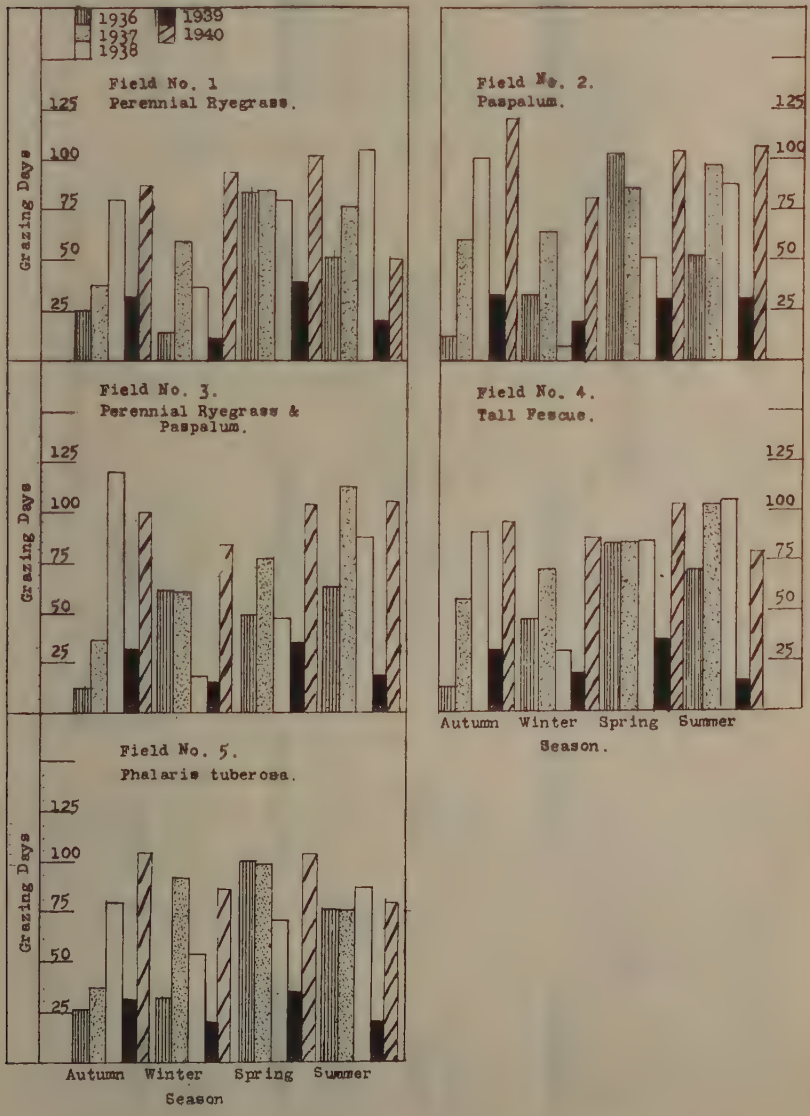
Year.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.
1936	176·5	199·1	191·3	214·7	235·4
1937	264·6	309·5	284·8	302·4	304·3
1938	306·3	245·4	275·4	309·8	292·4
1939	286·8	315·6	319·3	314·0	311·3
1940	341·7	440·0	441·0	383·5	404·0
Average for five years ...	275·2	301·9	302·4	304·9	309·5
Average for 1938–39–40 ...	311·6	333·7	345·2	335·8	335·9

It will be seen that over the whole period Phalaris tuberosa and tall fescue provided slightly more grazing than any of the other species. Perennial rye grass was somewhat lower than the other four species. Over the three years (1938, 1939, and 1940) the greater amount of grazing was obtained from plot 3

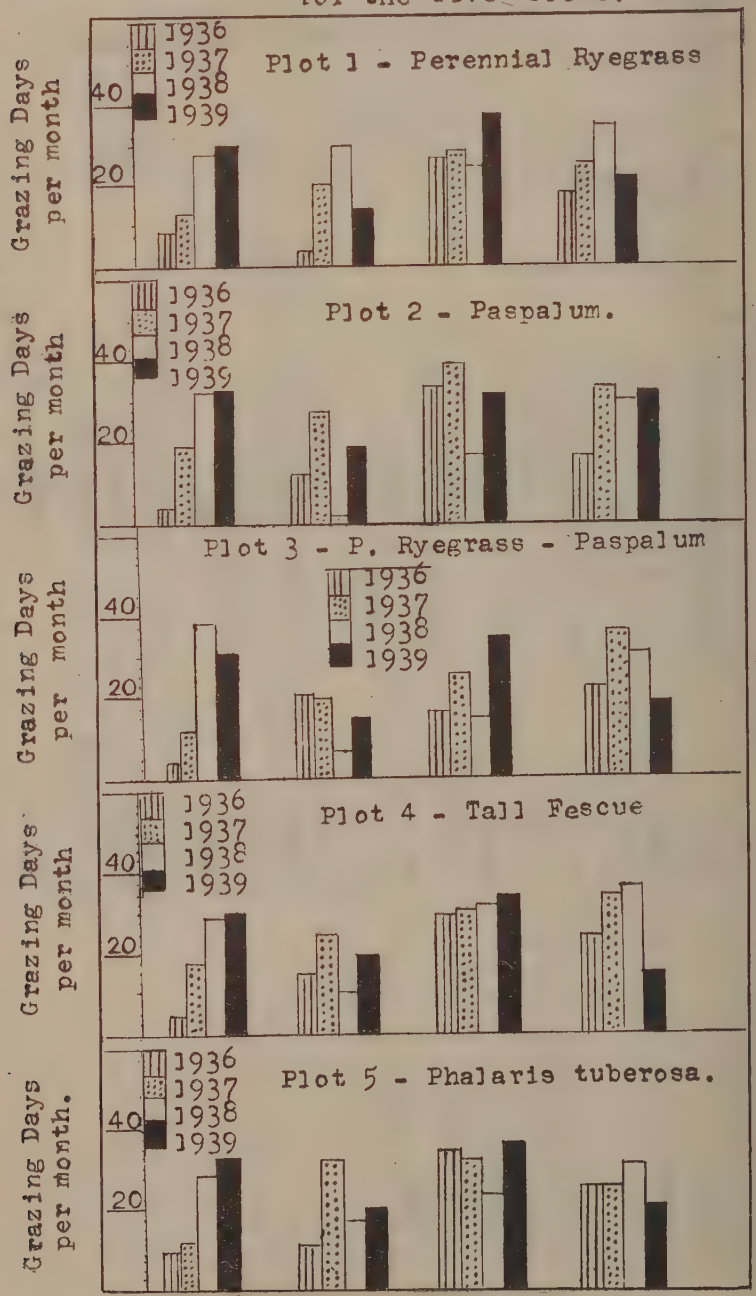
(paspalum and rye grass) while Phalaris, tall fescue and paspalum plots were almost equal and slightly lower than plot 3 and perennial rye grass gave the least grazing.

Graphs 3 and 3A show the seasonal grazing (3-monthly) throughout each year for each of the species.

Graph 3 - Three-Monthly Seasonal Grazing Days for the Five Fields.



Graph 3 A Three-monthly Seasonal Grazing Days for the Five Plots.



This graph emphasises the distribution of the grazing throughout the year for each of the species. Phalaris tuberosa shows slightly better winter grazing than any of the other species.

Yield.

The yield in tons of green material per acre is given in table 3, for the four years, 1937, 38, 39 and 40.

The highest yields were obtained during 1938 and since then yields have declined.

TABLE 3.

Year.	Tons per Acre.
1937	18·9
1938	23·9
1939	20·4
1940	15·11

Figures for production from each plot are shown in table 4.

TABLE 4.

PRODUCTION IN TONS PER ACRE FROM EACH OF THE FIVE FIELDS.

Year.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.
1937	20·90	18·40	19·00	18·60	17·30
1938	25·00	25·51	21·17	20·10	27·53
1939	17·23	25·41	18·25	19·01	22·29
1940	15·79	17·20	13·35	16·45	15·78
Average ...	19·73	21·63	17·94	18·54	20·73

The plots giving the highest average production over the four-year period were plot 2 (paspalum and white clover) and plot 5 (Phalaris tuberosa and white clover), whilst lowest in production were plot 3 (perennial rye grass and paspalum), and plot 4 (tall fescue).

Table 5 shows the seasonal yields from the whole area.

TABLE 5.

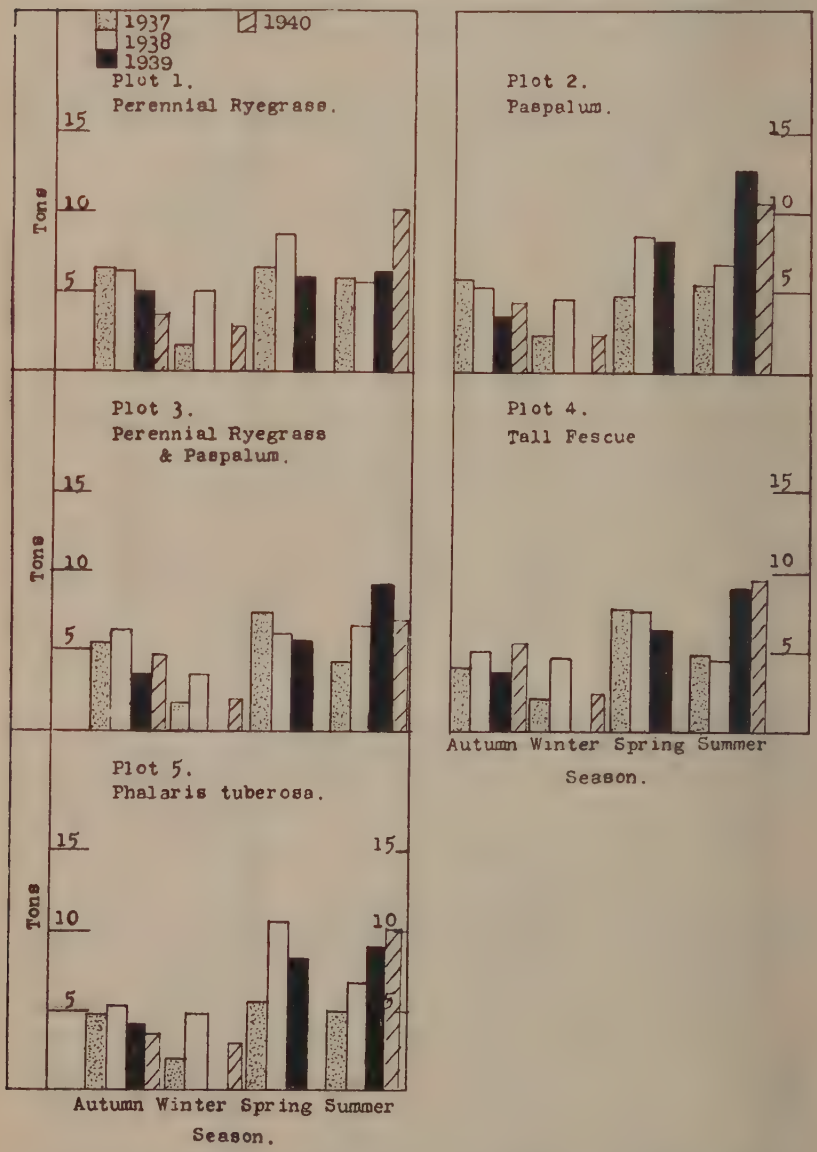
SEASONAL YIELDS FROM THE WHOLE AREA OVER THE FOUR-YEAR PERIOD.

Year.	Autumn.	Winter.	Spring.	Summer.
1937	3·7	2·0	6·4	6·8
1938	5·4	4·5	8·2	5·8
1939	4·0	...	7·1	9·1
1940	4·26	2·3	...	9·3

During 1937 and 1938 the yield was produced evenly throughout the year, but intermittently over 1939 and 1940.

Graph 4, gives a picture of the seasonal yields from each plot over the four-year period.

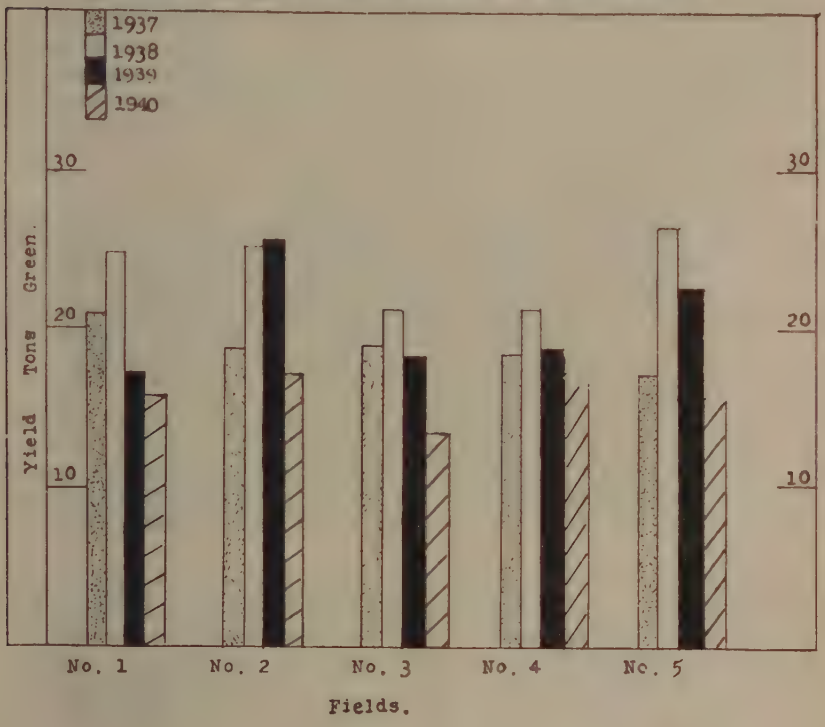
Graph 4. Three-Monthy Seasonal Yields for the Five Fields.



Perennial rye grass produced most even yields of all species whilst paspalum produced the greatest amount of herbage during the summer.

Graph 5 shows the production from each of the fields for the experimental period.

Graph 5. Annual Production in Tons for the Five Yields.



DISCUSSION.

Carrying Capacity.

Table 1 gives a summary of the grazing obtained over the five years during which the experiment has been in progress. In the establishment year the area carried one cow to 1.8 acres and increased in subsequent years to average one cow to 1.14 acres over the last four-year period. In comparison with a similar experiment conducted on the property of Mr. C. H. Henning, Hamel, this carrying capacity is somewhat low, but in view of the conditions appertaining to this particular area it is considered to be a reasonable return. The area was notably salty and the salt concentration made itself evident in the summer months and seriously affected the growth of the perennial species. Effective drainage was not obtained on this area with the result that flooding occurred during some of the winter periods. Grazing management of this particular area was difficult and the resultant management was intermittent and spasmodic. This management was not conducive to high production from the pastures. The sequence of overgrazing and undergrazing may be observed from graph 1A.

In spite of these adverse factors the improved species proved capable of carrying one cow to 1.14 acres and during 1940 the area carried one cow to 0.91 acres. As abovementioned difficulties may be overcome with greater care and supervision it is obvious that the carrying capacity may be increased beyond the average of one cow to 1.14 acres. The 1940 figure of one cow to 0.91 acres

may be somewhat deceptive. The production during this year was lower than the preceding years and the grazing was considerably greater. This suggests that the area may have been overgrazed during 1940 and the result of this overgrazing would probably show up in low grazing and production during 1941 had the experiment been continued into this year.

Consequently the trial has shown that the carrying capacity of this country on the experimental area was one cow to 1.14 acres and there is every indication that this can be further improved to a higher carrying capacity with greater care and attention.

Comparison of Species.

Phalaris tuberosa and white clover and tall fescue and white clover plots gave the greatest amount of grazing during the establishment year. On the two plots the progress of the grazing has been similar. An increase of about 40% occurred during 1937 and this level of grazing continued until a further rise was seconded in 1940. Over the whole period Phalaris tuberosa was somewhat superior to the tall fescue. The rise of 1940 is not easily reconciled to the climatic conditions nor to the production figures and as it has been experienced on all plots it is probably due to overgrazing.

Paspalum dilatatum and white clover, plot 2, produced somewhat less grazing during 1936 than either Phalaris tuberosa and white clover or tall fescue and white clover, an increase of about 56% was recorded for 1937, a fall of 20% occurred during 1938, but during the last two years a considerable increase is shown with the result that this plot ranks with No. 3 in producing most grazing during 1940.

Perennial rye grass and white clover in plot 1, provided least grazing in the year 1936, but increased by 50% in 1937 and still further in 1938. A slight decrease occurred during 1939 followed by an increase in 1940.

Plot 3 consisted of a combination of perennial rye grass and paspalum with white clover. During 1936 the amount of grazing was equal to that of plot 2 (paspalum alone). During 1938 the grazing was average between plot 1 (perennial rye grass and white clover) and plot 2 (paspalum and white clover). During 1938 an increase occurred on plot 1 and a decrease on plot 2, but plot 3 remained constant. This was due to the reaction of the separate species to their environment and the plot was just beginning to thicken up sufficiently. In the succeeding two years the dominating effect of paspalum was obvious from the close similarity of plots 2 and 3 in these two years. This dominating effect of paspalum was to some extent resultant on the type of grazing which occurred on these plots.

We must conclude that perennial rye grass is not so suitable as paspalum, tall fescue or Phalaris tuberosa under the existing conditions of management and soil conditions.

In respect to the provision of grazing during the winter months Phalaris tuberosa provided the greatest amount but the tall fescue and the perennial rye grass-paspalum combination also provided a considerable amount.

Paspalum and white clover alone and perennial rye grass and white clover alone failed to provide as much winter grazing as did the other plots.

The most suitable species for this district and under these conditions appear to be Phalaris tuberosa and paspalum-perennial rye grass mixture grown in association with white clover.

Yields.

Up to 1938 the grazing management had been more or less efficient, but during 1939 and 1940 a decrease in this efficiency was noticeable. The result has been a decrease in production from four of the plots in 1939 and a decrease on all five plots in 1940. Thus even though a substantial increase in grazing occurred on all plots during 1940 there was a serious decline in production. Consequently the plots must have been seriously over-grazed during 1940. This over-grazing and consequent damaging of the pastures resulted in lower production figures for 1939 and 1940, despite the fact that by this, all the species had sufficient time to become firmly established. The highest production figure was recorded in 1938 when 23.9 tons of green material was obtained per acre.

In agreement with the grazing figures already discussed greatest production over the five-year period was obtained from plots 2 and 5, that is from paspalum and white clover and Phalaris tuberosa and white clover. The greatest individual production for any one year was produced by Phalaris tuberosa and white clover when 27.5 tons per acre were cut in 1938.

Over the four-year period 1937-1940, paspalum and white clover and Phalaris tuberosa and white clover gave the greatest yields which averaged respectively for the four-year period 21.63 tons per acre and 20.73 tons per acre.

The seasonal production reflected the effect of the grazing management, particularly during 1939 and 1940. During 1939 winter production was nil and during 1940 the spring production was nil. This variation is shown graphically in graph 5 and extends to all species.

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Page 175, Table II, lines 1, 4, 6, and 8 *for* "supplies," *read* "suppliers," and in lines 2 to 9, *delete* the words "to gain maximum points for bacteria."

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